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MEDICAL APPLIED ANATOMY

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MEDICAL APPLIED ANATOMY

FOR STUDENTS AND PRACTITIONERS

BY

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AND LECTURER ON MEDICAL APPLIED ANATOMY
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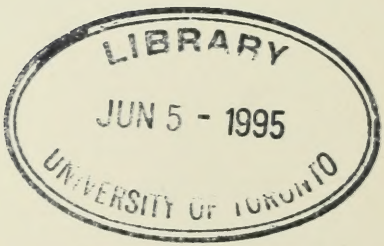
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PREFACE

For the last four years it has been my privilege to conduct a short course of lectures on Medical Applied Anatomy in connexion with the Edinburgh Post-Graduate Courses in Medicine and Surgery. At the suggestion of Dr. J. D. Comrie, the Medical Editor of the Edinburgh Medical Series, these lectures have been collected and expanded and are now issued in book form.

As the realms of Medicine and Surgery are not sharply separated from one another, it has been a matter of some difficulty to avoid encroaching on the domain of Surgical Applied Anatomy, but the endeavour has been made to restrict the subject-matter so as to present, at moderate length, the more important applications of Anatomy to the study of Clinical Medicine. On this account, the subject has been treated according to Systems and not according to Regions, and it is hoped that the grouping of muscles with their nerves of supply under the Nervous System will be found useful by the reader.

In collecting the material for this book, I have necessarily been indebted to the published works of numerous authors, and, more particularly, I wish to express my great indebtedness to the writings of Mackenzie, Sahli, and Purves Stewart.

For numerous suggestions and much helpful advice, always freely and willingly given, I owe my warmest thanks to Dr. J. D. Comrie. In addition, I gratefully acknowledge the help given me by Dr. A. Murray Drennan, who assisted in the laborious task of proof-reading, and by Dr. E. B. Jamieson, whose criticisms have always been of the greatest value.

Some of the illustrations have appeared previously in other works. Figures 7, 8, 12, 15, 32, 33, 35, 36, 38, 39, 44, 49, 51, 53, 55, 58, 79, 82, 114, and 115 are taken from Hirschfeld

and Leveillé's *Atlas of Neurology*. Their accuracy and artistic finish render no apology necessary for their reproduction in this book. The tracings reproduced in Figures 107, 111, and 112 were obtained for me by Dr. G. D. Mathewson, to whom I am greatly indebted. I wish to express my appreciation of the kindness of Dr. Knox, who helped to select and permitted me to reproduce three illustrations from his work on *Radiography*. I have also to thank Dr. S. G. Scott and Mr. Chas. A. Clark, who most kindly provided me with the radiographs which appear as Figures 142 and 84, respectively.

At the present time anatomical nomenclature, so far as anatomical teaching is concerned, is unfortunately in a very chaotic condition. Until some general agreement can be come to with regard to this matter, not only by Anatomists, but also by all who are interested in the study and teaching of the Medical Sciences, no nomenclature can be regarded as completely satisfactory. In this book the Bâle terminology, which has now been adopted in several medical schools in this country, has been used to a large extent, but the old and better known names have been inserted in brackets, wherever the possibility of confusion has arisen. The terms *medial* and *lateral*, however, have been used throughout in place of *internal* and *external*, and it has been considered unnecessary to insert the latter terms in brackets. It is hoped that the Glossary may be useful to those teachers of Clinical Medicine who desire to familiarise themselves with the Bâle terminology. It must, however, be clearly understood that the Glossary contains only those terms which are commonly used in Clinical Medicine and which are not identical in the two terminologies.

In conclusion, I hope that the book may prove of service and of interest, not only to the general practitioner, but also to the medical student during his study of Clinical Medicine.

LONDON, *December* 1914.

CONTENTS

I

PAGE

THE NERVOUS SYSTEM 1

Development—The Neurone—The Brain—The Brain-Stem—The Motor Path—The Spinal Medulla—The Cerebral Nerves—The Membranes of the Brain—The Spinal Nerves—The Brachial Plexus—The Intercostal Nerves—The Lumbar Plexus—The Sacral Plexus—The Sympathetic Nervous System—Referred Pain.

II

THE ORGANS OF SPECIAL SENSE . . . 198

The Ear—The Eye—The Nose.

III

THE DIGESTIVE SYSTEM 219

The Teeth — The Salivary Glands — The Mouth — The Pharynx — The Œsophagus — The Peritoneum — The Stomach—The Small Intestine—The Liver and Bile Ducts — The Pancreas — The Portal Circulation — The Large Intestine—Developmental Anomalies.

IV

THE VASCULAR SYSTEM 288

The Pericardium—The Heart—The Fœtal Circulation—Congenital Anomalies—Cardiac Pain—The Heart Musculature—The Venous Pulse—The Heart Rhythm—The Great Vessels.

V

PAGE

THE RESPIRATORY SYSTEM 325

The Nose—The Naso-Pharynx—The Larynx—The Trachea and Bronchi—The Pleural Sacs—The Lungs.

VI

THE GENITO-URINARY SYSTEM 357

The Kidneys—The Ureter—The Bladder—Congenital Anomalies—The Prostate—The Testis—The Urethra—The Female Pelvis and Reproductive Organs.

VII

THE DUCTLESS GLANDS 400

The Hypophysis—The Spleen—The Supra-renal Glands—The Thyreoid Gland—The Thymus.

GLOSSARY 415

INDEX 423

LIST OF ILLUSTRATIONS

COLOURED PLATES

PLATE

I. The Postero-inferior Aspect of the Liver . . *facing p.* 260

II. General View of the Abdominal and Thoracic Viscera } *between pp.* 344

III. The Abdominal and Thoracic Viscera from behind } *and* 345

IN THE TEXT

FIG.		PAGE
1.	Transverse Section of Human Embryo	1
2.	Section through cephalad extremity of Neural Tube . .	2
3.	Lateral Aspect of Left Cerebral Hemisphere . . .	6
4.	Lateral Aspect of Skull, showing the relations of important structures to the surface	7
5.	Median Sagittal Section through the Brain-Stem, showing the third and fourth ventricles and their connexions . .	11
6.	Medial Aspect of Right Cerebral Hemisphere . . .	13
7.	The Tela Chorioidea (velum interpositum) viewed from above .	14
8.	The Inferior Aspect of the Brain	17
9.	Medial Aspect of Right Cerebral Hemisphere . . .	18
10.	Transverse Section through the Mid-Brain . . .	19
11.	The Lateral Aspect of the Brain-Stem	19
12.	The Anterior Aspect of the Brain-Stem	20
13.	Dissection to show the Floor of the Lateral Ventricle. (Turner's *Anatomy*.)	24
14.	Median Sagittal Section through the Brain-Stem, showing the third and fourth ventricles and their connexions . .	25
15.	The Tela Chorioidea (velum interpositum) viewed from above .	26
16.	Lateral Aspect of Skull, showing the relations of important structures to the surface	28
17.	The Lateral Aspect of the Brain-Stem	29
18.	Horizontal Section through Left Cerebral Hemisphere . .	31

FIG.		PAGE
19.	Frontal (Coronal) Section through Left Cerebral Hemisphere	32
20.	Diagram to illustrate Innervation of a Muscle by both Cerebral Hemispheres	34
21.	Dissection of Brain, showing the Lateral Aspect of the Internal Capsule	36
22.	Diagram of Frontal (Coronal) Section of Right Cerebral Hemisphere and Brain-Stem, showing the path of the Motor Fibres	38
23.	Transverse Section through the Pons (Diagrammatic)	40
24.	Fœtal Skull, seen from above. (Johnstone's *Midwifery*.)	42
25.	Transverse Section through Spinal Medulla (Schematic)	44
26.	Diagram to illustrate the course taken by Sensory Fibres after entering the Spinal Medulla	45
27.	Floor of Skull	49
28.	Diagram of course of Visual and Pupillary Fibres	50
29.	The Lateral Aspect of the Brain-Stem	51
30.	Dissection of Brain, showing the Lateral Aspect of the Internal Capsule	53
31.	Transverse Section through the Cavernous Sinus	55
32.	The Posterior Aspect of the Brain-Stem	56
33.	The Muscles of the Orbit	59
34.	Transverse Section through the Pons (Diagrammatic)	62
35.	Interior of the Skull after the removal of the Brain, showing the points of exit of the twelve cerebral nerves	63
36.	The Branches of the Ophthalmic Nerve	64
37.	The Cutaneous Branches of the Trigeminal Nerve	66
38.	The Branches of the Maxillary Nerve	67
39.	The Branches of the Mandibular Nerve	71
40.	The Cutaneous Branches of the Trigeminal Nerve	74
41.	The Areas of Skin supplied by the three divisions of the Trigeminal Nerve	76
42.	Transverse Section through the Pons (Diagrammatic)	79
43.	Schematic representation of the Branches of the Facial Nerve	81
44.	The Facial Nerve and its Ramifications	83
45.	Schematic representation of the course of the Taste Fibres	85
46.	Diagram to show the path of the Fibres of the Cochlear Nerve	88
47.	Section through Upper Part of Medulla Oblongata	91
48.	The Lateral Aspects of the Larynx and Pharynx, showing their Nerves of Supply	93
49.	The Course, Relations and Branches of the Left Vagus Nerve	95
50.	Transverse Section through the Neck at the level of the First Thoracic Vertebra	98
51.	Interior of the Skull after the removal of the Brain, showing the points of exit of the twelve cerebral nerves	102

FIG. PAGE
52. Section through Upper Part of Medulla Oblongata . . 105
53. The Cranial Blood Sinuses 110
54. Median Sagittal Section through the Brain-Stem, showing the third and fourth ventricles and their connexions . . 112
55. The Cranial Blood Sinuses 113
56. Transverse Section through the Cavernous Sinus . . 115
57. Lateral Aspect of Skull, showing the relations of important structures to the surface 117
58. Interior of the Skull after the removal of the Brain, showing the points of exit of the twelve cerebral nerves . . . 118
59. Diagram to illustrate the course taken by Sensory Fibres after entering the Spinal Medulla 123
60. The Areas of Skin supplied by the Posterior Rami (primary divisions) of the Spinal Nerves 125
61. The Nerve-supply of the Anterior Aspect of the Trunk . 127
62. Diagram to show the branches and the mode of formation of the Cervical and the Brachial Plexuses. (Turner's *Anatomy*.) 130
63. The Nerve-supply of the Skin on the Anterior Aspect of the Upper Limb 135
64. The Nerve-supply of the Skin on the Dorsal Aspect of the Upper Limb 139
65. The Nerve-supply of the Skin on the Anterior Aspect of the Upper Limb 143
66. Tendons attached to a Finger. (Turner's *Anatomy*.) . . 146
67. The Nerve-supply of the Skin on the Dorsal Aspect of the Upper Limb 153
68. Diagram representing the development of the Upper Limb, and the segmental arrangement of its Sensory Nerve-supply . 158
69. The Nerve-supply of the Anterior Aspect of the Trunk . . 161
70. The Lumbar, Sacral and Pudendal Plexuses. (Turner's *Anatomy*.) 164
71. The Nerve-supply of the Skin on the Anterior Aspect of the Lower Limb 168
72. The Lumbar, Sacral and Pudendal Plexuses. (Turner's *Anatomy*.) 171
73. The Nerve-supply of the Skin on the Anterior Aspect of the Lower Limb 179
74. The Nerve-supply of the Skin on the Posterior Aspect of the Lower Limb 181
75. Diagram of the Sympathetic Nervous System . . . 186
76. Diagram to explain a Viscero-sensory Reflex . . . 191
77. Section through the Auricle, the External Acoustic Meatus and the Tympanum. (Turner's *Anatomy*.) . . 201

FIG.		PAGE
78.	Lateral Aspect of Right Tympanic Membrane	203
79.	The Facial Nerve traversing the Facial Canal in the Petrous Part of the Temporal Bone	204
80.	Diagram of the Membranous Labyrinth. (Turner's *Anatomy*.)	207
81.	The Lacrimal Apparatus. (Turner's *Anatomy*.)	209
82.	Antero-Posterior Median Section through the Eyeball	213
83.	The Normal Fundus, showing the Porus Opticus (Optic Disc) and the Retinal Blood-vessels	217
84.	Radiogram of Anterior Portion of Head, showing non-eruption of the third upper molar tooth of the right side. (From a Radiography by Chas. A. Clark, Esq., L.D.S.Eng.)	221
85.	The Parotid Gland and its Duct	223
86.	The Interior of the Pharynx, viewed from behind	227
87.	Anterior Aspect of Trunk, showing the planes utilised for the surface topography of the abdominal viscera	233
88.	Median Sagittal Section through the Abdomen, to show the arrangement of the Peritoneum. (Turner's *Anatomy*.)	235
89.	Diagram of the Stomach and the Lesser Omentum	236
90.	Transverse Section through the Abdomen at the level of the epiploic foramen (of Winslow), to show the disposition of the Peritoneum	238
91.	Transverse Section through the Abdomen, below the level of the epiploic foramen (of Winslow)	239
92.	Anterior Aspect of the Trunk, showing the surface relations of the liver, the stomach and the large intestine	244
93.	The relations of the Left Kidney and the Viscera which form the "bed" of the Stomach	245
94.	Normal Tonic Stomach. (From Knox's *Radiography*.)	246
95.	Atonic, dilated, Stomach. (From Knox's *Radiography*.)	247
96.	The Nerve-supply of the Anterior Aspect of the Trunk	251
97.	The relations of the Right Kidney, the Duodenum and the Head of the Pancreas	254
98.	Diagram of the Bile Duct and the Pancreatic Ducts, showing how they open into the Duodenum	263
99.	The relations of the Right Kidney, the Duodenum and the Head of the Pancreas	267
100.	The Portal Vein and its Tributaries. (Turner's *Anatomy*.)	273
101.	Anterior Aspect of the Trunk, showing the surface relations of the liver, the stomach and the large intestine	277
102.	The Rectal Valves	282
103.	The Development of the Bladder and Recturn	286
104.	Diagram of a Sagittal Section through the Heart and the Pericardium	289

FIG. PAGE
105. Diagram of a Transverse Section through the upper part of the Pericardium 290
106. Anterior Aspect of the Chest, showing the surface relations of the heart and great vessels, the lungs and the pleural sacs . 295
107. Sphygmographic Tracing of a Normal Pulse . . . 301
108. Diagram to show the positions of the valves on the tributaries of the Superior Vena Cava 302
109. Diagram of the primitive tubular Heart of the Embryo . 303
110. Diagram to illustrate the Fœtal Circulation . . . 305
111. Tracing of the Normal Venous Pulse, together with a synchronous tracing of the Radial Pulse . . . 311
112. Tracings from a case of Complete Heart-block . . . 313
113. Transverse Section through the Thorax at the level of the fourth thoracic vertebra 320
114. The Nasal Septum 326
115. Frontal (Coronal) Section through the Skull, showing the nasal fossæ 328
116. Posterior Aspect of the Cartilages of the Larynx. (Turner's *Anatomy*.) 331
117. The Interior of the Pharynx viewed from behind . . 333
118. Frontal (Coronal) Section through the Larynx. (Turner's *Anatomy*.) 334
119. The Interior of the Left Half of the Larynx. (Turner's *Anatomy*.) 336
120. Tranverse Section through the Larynx at the level of the vocal folds (true vocal cords). (Turner's *Anatomy*.) . . 337
121. The Larynx, Trachea and Bronchi 340
122. Diagram of a Transverse Section through the Thorax above the level of the root of the lung, showing the arrangement of the parietal and visceral layers of the pleura . . 342
123. Diagram of a Transverse Section through the Thorax at the level of the root of the lung. The continuity of the visceral and the parietal layers is demonstrated in the figure . 343
124. Anterior Aspect of the Trunk, showing the surface relations of the kidneys and ureters, the duodenum and the pancreas . 358
125. The relations of the Left Kidney and the Viscera which form the "bed" of the Stomach 359
126. The Spleen and the Left Kidney and Ureter outlined on the Dorsal Aspect of the Body 362
127. Median Sagittal Section of Male Pelvis, showing the relations of the viscera and the arrangement of the peritoneum . 366
128. Median Sagittal Section through Male Pelvis, showing the disposition of the peritoneum when the bladder is distended 368

FIG. PAGE
129. The Development of the Bladder 370
130. The Nerve-supply of the Anterior Aspect of the Trunk . . 372
131. Diagram of the Male Reproductive Organs. (Turner's *Anatomy*.) 376
132. The Urinary Bladder and the Prostate, viewed from behind . 378
133. The Development of the Male Reproductive Organs . . 381
134. Median Sagittal Section through the Female Pelvis, showing the relations of the viscera and the arrangement of the peritoneum 384
135. Diagram of a Sagittal Section through the Broad Ligament of the Uterus and its contents 385
136. Diagram of a Transverse Section through the Uterus and the Broad Ligaments, near the lower borders of the latter, showing the relation of the uterine artery to the ureter . 386
137. The Uterus and the Broad Ligaments, viewed from in front. (Turner's *Anatomy*.) 390
138. Diagram of a Transverse Section through the Uterus and the Broad Ligaments, near the lower borders of the latter, showing the relation of the uterine artery to the ureter . 392
139. The Broad Ligaments of the Uterus, viewed from behind. (Turner's *Anatomy*.) 394
140. Diagram of the Development of the Female Generative Organs 397
141. Radiogram of Skull, showing a normal hypophyseal (pituitary) fossa. (From Knox's *Radiography*.) . . . 401
142. A much enlarged Hypophyseal Fossa, caused by a tumour of the Hypophysis (pituitary body). (From a Radiograph taken by Dr. S. G. Scott.) 402
143. The Spleen and the Left Kidney and Ureter outlined on the Dorsal Aspect of the Body 403
144. Transverse Section through the Abdomen at the level of the epiploic foramen (of Winslow), to show the disposition of the peritoneum 405
145. The relations of the Left Kidney and the Viscera which form the "bed" of the Stomach 407
146. Transverse Section through the Neck at the level of the First Thoracic Vertebra 410

MEDICAL APPLIED ANATOMY

I

THE NERVOUS SYSTEM

Development of the Nervous System.—Before the different parts of the nervous system are described, it is necessary to outline, as briefly as possible, the developmental history of the nervous system as a whole.

During the first week of intra-uterine life, a longitudinal

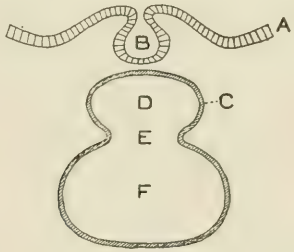


FIG. 1.—Transverse Section of Human Embryo.

A. Ectoderm. | *B*. Neural groove. | *C*. Endoderm. | *D*. Mid-gut. | *E* Vitello-intestinal duct. | *F*. Yolk-sac.

groove, which rapidly increases in depth, appears in the ectoderm on the dorsal surface of the human embryo (Fig. 1). At a slightly later stage, the edges of the groove coalesce so as to form a tube, which soon loses its connexion with the surface ectoderm. This tube is lined entirely by ectoderm

and it subsequently gives rise to the whole of the nervous system.

From the lateral walls of the cephalic (or anterior) extremity of the neural tube, which persists in the adult as the third ventricle, two diverticula grow out, one on each side, and form the cerebral hemispheres. The cavities of the diverticula persist as the lateral ventricles and their connexions with the primitive tube remain in the adult as the interventricular foramina (of Monro) (Fig. 2).

The fourth ventricle arises as a dilatation of the neural tube, caudal to the lateral diverticula, and the part of the tube immediately cephalad to this dilatation subsequently forms

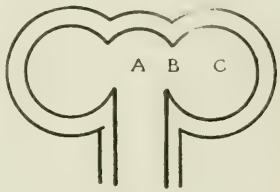


FIG. 2.—Section through cephalad extremity of Neural Tube.

A. Neural tube. *B*. Primitive interventricular foramen (of Monro). *C*. Developing lateral ventricle.

the cerebral aqueduct (of Sylvius), which connects the fourth ventricle with the third ventricle in the adult (p. 15). The caudal (or posterior) portion of the tube persists as the central canal of the spinal medulla (spinal cord).

The ectodermal cells which line the neural tube undergo specialisation. Some of them are converted into nerve-cells; others form the neuroglia, which constitutes the supporting tissue of the nervous system; while others form the ependyma, which lines the whole of the interior of the ventricular system. Over the caudal part of the roof of the fourth ventricle the ectoderm gives rise only to ependyma, so that in this situation the ependyma comes into direct contact with the overlying pia mater (p. 111).

The Neurone.—Each nerve-cell consists of a body, variously shaped and containing a nucleus, a nucleolus, etc., and certain processes. The processes are of two kinds—(*a*) the *dendrites*, which are usually short and break up into numerous branches, and (*b*) the *axon* or axis cylinder, which varies in length and gives off no branches of note prior to its termination.

Physiologically, so far as we know at present, the axon is of much greater importance than the dendrites, and impulses arising within the cell, or destined for it, are transmitted along the axon.

The term "NEURONE" includes the nerve-cell and all its processes. Neurones can be divided, broadly, into two groups:—(*a*) Those engaged in carrying impulses from the cerebral cortex to the periphery, *efferent neurones*; and (*b*) those engaged in carrying impulses from the periphery to the cerebral cortex, *afferent neurones*.

Efferent stimuli arising in the cortex traverse two or more neurones before they reach their destination, and these neurones must all be physiologically intact before the stimulus can produce its result. The uppermost neurone has its cell situated in the cerebral cortex and the lowermost neurone has its cell in the grey matter of the brain stem or the spinal medulla (spinal cord). In the case of the voluntary muscles, *interruption of the upper neurone* prevents the stimulus from passing on to its destination and the muscle involved is paralysed, *i.e.* it is unable to react to cerebral stimuli, although its electrical reactions are not altered. As the lower neurone is not damaged, the trophic influence which the nerve-cells exert on the tissues they supply is not interfered with and the muscle involved will suffer atrophy from disuse only. In addition to originating voluntary stimuli, the upper neurone exerts a subconscious controlling action on the lower neurone and, when this controlling action is removed, the muscle, typically, assumes a spastic contraction. On the other hand, *when the lower neurones are interrupted*, their axons are cut off from the cell body and undergo degeneration.

As a result, the muscle involved is not only paralysed but its electrical reactions become altered. Further, the trophic influence of the lower neurone being removed, the muscle atrophies. At the same time, the controlling "tonic" influence is cut off and the muscle, losing its tonus, becomes flaccid.

Afferent stimuli have their origin in the periphery, often in special nerve-endings, and they pass along the axons to the spinal medulla. Either in the spinal medulla or in the brain stem the axons end by arborising round nerve-cells and the impulses which they convey are transferred to these upper neurones. After passing through one, two or more relays, the afferent impulse eventually reaches the cortex and, depending on its nature, is interpreted or causes a reacting efferent impulse.

Under normal conditions, an afferent impulse stimulates only a group of axons and the neurones to which they belong, and then is transmitted to the cerebral cortex; but, under abnormal conditions, an afferent impulse may spread from the cells for which it was primarily intended and affect the neighbouring nerve-cells. Of the nature of this "overflow" we know as little as we do about the nature of the original impulse, but, apparently, stimulation of a neurone by "overflow" from adjoining neurones produces precisely the same results as stimulation arising at its peripheral part. In this way, impulses ascending along the phrenic nerve (C, 3, 4 and 5) reach nerve-cells in the fourth cervical segment, and, when these impulses are altered, as in diaphragmatic pleurisy, they may overflow and stimulate the adjoining cells, which normally receive peripheral stimuli only from the skin of the neck and shoulder. Such an overflow therefore causes stimuli to reach nerve-cells in the cortex, and these cells interpret all stimuli as pain in the region of the neck and shoulder. Pain of this nature is termed "referred pain." The condition is described more fully in connection with Mackenzie's "Viscero-Sensory" and "Viscero-motor Reflexes" on page 190.

THE BRAIN

The Parts of the Central Nervous System.—The Brain is divided into two symmetrical *hemispheres* by the *great longitudinal fissure*, but the two halves are connected to one another by commissural bands, of which the corpus callosum (p. 10) is the most important. The **mid-brain** descends from the middle of the basal surface of the brain and is continuous below with the **pons**, which in turn becomes continuous with the **medulla oblongata.** These three structures form the **brain-stem** and, together with the **cerebellum**, which projects backwards behind them, they occupy the posterior cranial fossa. At the foramen magnum in the occipital bone the medulla oblongata becomes continuous with the **spinal medulla** (spinal cord).

The Lateral Surface of the Brain

The **Central Sulcus (of Rolando)** is the most important sulcus on the lateral surface of the cerebral hemisphere. It is directed obliquely downwards and forwards and is situated between two parallel and nearly vertical convolutions, which are termed the *anterior* and the *posterior central gyri.* Inferiorly, the central sulcus terminates a little above the posterior ramus of the lateral fissure (of Sylvius) (Fig. 3).

The grey matter of the anterior central gyrus and of the anterior wall of the central sulcus contains the **higher motor centres.** The *centre for the muscles of the lower limb* is situated in the uppermost part of the anterior central gyrus, and it extends over the supero-medial border of the hemisphere for a short distance on to the medial surface (Fig. 6). Immediately below the centre for the lower limb, and slightly overlapping it, lies the *centre for the muscles of the trunk*, while the *upper limb centre* is placed a little lower and occupies that part of the anterior central gyrus which projects backwards following the curve of the central sulcus

(Fig. 3). The lowest part of the anterior central gyrus contains the *motor centres for the face, head and neck.*

Before the axons from the nerve-cells of the motor area of the cortex reach their destination, they all, with certain exceptions to be noted later (pp. 34 and 86), cross the median plane. *Cortical lesions* in this situation, therefore, produce their effects on the opposite side of the body and,

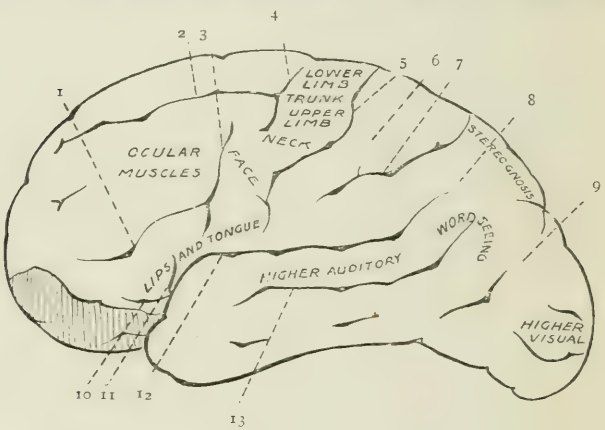


FIG. 3.—Lateral Aspect of Left Cerebral Hemisphere.

1. Inferior frontal sulcus.
2. Superior frontal sulcus.
3. Inferior precentral sulcus.
4. Superior precentral sulcus.
5. Central sulcus (of Rolando).
6. Posterior central gyrus.
7. Post-central sulcus.
8. Supra-marginal gyrus.
9. Post-parietal gyrus.
10. 11. 12. Rami of lateral fissure (of Sylvius).
13. Superior temporal sulcus.

owing to the extent of the anterior central gyrus, they are not likely to involve the whole of the motor area. The effects of the lesion may be irritative or paralytic, according to its nature, or the second condition may ensue after a temporary irritative stage. Irritative conditions of the motor cortex do not necessarily depend on the existence of an organic lesion, and in many cases of epilepsy no such lesion is present.

Organic lesions, sooner or later, lead to paralysis, which is usually distributed over two regions, whose centres overlap one another in the anterior central gyrus. A pure monoplegia of cortical origin is extremely rare and, when it does

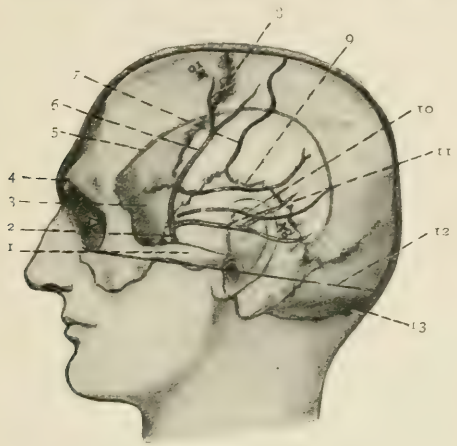


FIG. 4.—Lateral Aspect of Skull, showing the relations of important structures to the surface.

1. Zygomatic arch.
2. Middle meningeal artery.
3. Greater wing of sphenoid.
4. Glabella.
5. Temporal line.
6. Anterior branch of middle meningeal artery.
7. Central sulcus (of Rolando).
8. Coronal suture.
9. Lateral fissure, posterior ramus.
10. Superior temporal sulcus.
11. Posterior branch of middle meningeal artery.
12. Line drawn from floor of orbit through centre of external acoustic meatus.
13. External occipital protuberance.
o^1. Site for puncture of lateral ventricle.
o^2. Site for puncture of inferior horn of lateral ventricle.

occur, it involves the lower limb. The condition is diagnostic of a lesion in the posterior part of the medial surface of the frontal lobe (Fig. 6).

The upper extremity of the central sulcus corresponds on the surface of the skull to a point which lies half an inch behind the mid-point of the line joining the *glabella* (the

elevation immediately above the root of the nose) to the *external occipital protuberance*; its lower extremity lies 2 inches vertically above the *pre-auricular point*, which is situated on the zygomatic process of the temporal bone immediately in front of the tragus of the external ear. The line joining these two points indicates, on the surface of the head, the position and direction of the central sulcus, and the area which extends for three-quarters of an inch anterior to it overlies the anterior central gyrus. Firm pressure or percussion over this area may produce pain in organic lesions of the motor cortex.

The **Middle Frontal Gyrus** lies anterior to the middle third of the anterior central gyrus, from which it is separated by the precentral sulci (Fig. 3). It is said to contain the motor centres for the muscles of the eye. Turner and Ferrier removed this portion of the cortex in monkeys, but, although the operation produced temporary conjugate deviation of the head and eyes towards the side of the lesion, the condition was rapidly recovered from, and the animal regained free control over all the muscles of the eye and the head and neck. Irritative lesions in this region may give rise to deviation of the head and eyes to the opposite side, but the great majority of such lesions give rise to no localising motor symptoms unless they extend backwards and involve the anterior central gyrus.

Lesions of the frontal lobe, anterior to the precentral sulcus, may give rise to mental symptoms, but these vary so much that they are not of great help in topical diagnosis. Failure of memory, alterations in personal disposition, loss of concentrative powers, are features which have been noted in some cases.

The posterior part of the middle frontal gyrus is said to contain the *higher centres for written speech*. In cortical lesions of this area the patient is unable to write intelligible sentences or words, although he can read and speak quite intelligently and understands what is said to him.

The **Lateral Fissure (of Sylvius)** begins on the basal

surface of the brain at the lateral side of the *anterior perforated substance* (*ant. perf. spot*) (p. 16) and passes laterally, separating the temporal from the frontal lobe. When it reaches the lateral surface of the brain, it divides into three rami. The anterior horizontal and the anterior ascending rami pass forwards and upwards, respectively, into the inferior frontal gyrus, and the cortical areas which surround them constitute the *area of Broca*. The *motor speech centre* is situated in this area, on the left side of the brain in right-handed subjects and on the right side of the brain in left-handed subjects. Cortical lesions of Broca's area cause motor aphasia, but, if the lesion is localised, the patient can understand what is said to him and can read and write intelligently.

The *posterior ramus* of the lateral fissure runs backwards, separating the frontal and parietal lobes above from the temporal lobe below, and finally it turns upwards to end in the parietal lobe. At its termination it is surrounded by the **supramarginal gyrus**, which lies under cover of the *parietal tuber* (*eminence*) (Fig. 4).

The **Superior Temporal Sulcus** lies in the temporal lobe below and parallel to the posterior ramus of the lateral fissure, and it also turns upwards to end in the parietal lobe. Its extremity is surrounded by the **angular gyrus**, which contains the *visual speech centre*. In cortical lesions of this gyrus, the patient cannot understand written or printed matter, although otherwise his vision may be quite unaffected and he can speak and write intelligibly. The latter action may be carried out with difficulty, as he cannot appreciate whether he is writing sense or nonsense.

The **Superior Temporal Gyrus** lies between the posterior ramus of the lateral fissure above and the superior temporal sulcus below. It contains the *higher auditory* and *word-hearing centres* and, when involved in pathological conditions, it gives rise to partial deafness of the opposite ear (p. 89).

The **Superior Parietal Gyrus** is a strip of cortex which is

situated between the supero-medial border of the hemisphere and the angular and supramarginal gyri. From the two latter it is separated by the ramus horizontalis of the post-central sulcus. It is believed to contain the centre for *stereognosis*, the sense by which objects can be identified by tactile impressions only. When symptoms of cerebral tumour are present, the development of astereognosis. indicates that the tumour is situated in the neighbourhood of the superior parietal gyrus. Cases of astereognosis have also been recorded in which the lesion has been confined to the supramarginal convolution (Fig. 3).

The posterior part of the lateral surface of the cerebrum belongs to the **occipital lobe**. This portion of the cortex contains some of the *higher visual centres*, but as they appear to be connected more intimately with the medial surface of the occipital lobe, their description is deferred until that aspect of the brain is described (p. 12).

When the lips of the posterior ramus of the lateral fissure are drawn apart, a submerged area of the cerebral cortex is brought into view. This area is termed the **Island (of Reil)**. It is of value as a landmark in the study of sections of the brain which pass through the anterior part of the cerebral hemisphere (Fig. 18). Practically nothing is known about its functions, and, although Campbell has suggested that its anterior portion contains the higher centres for the sense of taste, his views have no clinical evidence to support them.

The Medial Surface of the Cerebral Hemisphere

The most noticeable structure on the medial surface is the **Corpus Callosum.** It consists of white matter, the fibres of which run mainly in a transverse direction and connect cortical areas of one hemisphere to the corresponding areas of the other. The posterior extremity of the corpus callosum, which is termed the *splenium*, forms a rounded swelling, overhanging the posterior aspect of the mid-brain (Fig. 5). The *body*

of the corpus callosum extends forwards from the splenium to the *genu*, where it bends sharply downwards and backwards to end in a pointed extremity, which is termed the *rostrum*.

Cases of maldevelopment or congenital absence of the corpus callosum have been recorded, but, although some

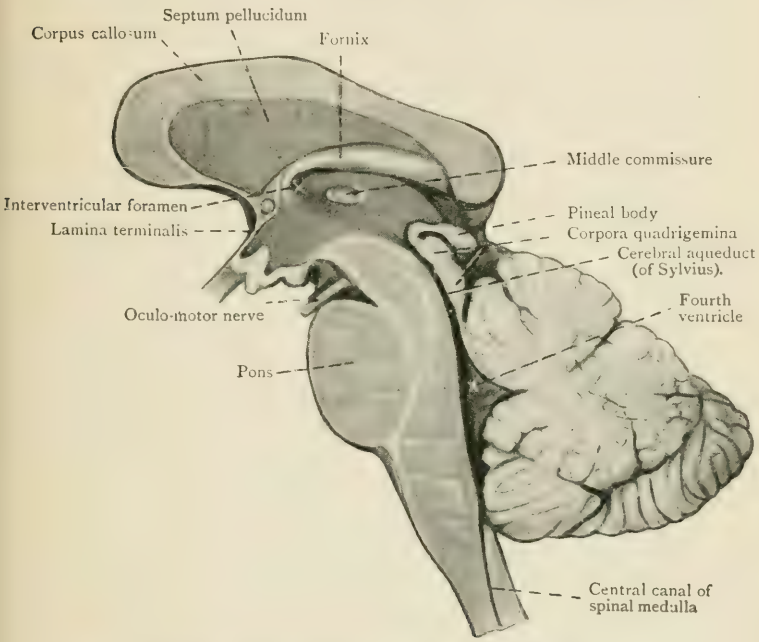


FIG. 5.—Median Sagittal Section through the Brain-Stem, showing the third and fourth ventricles and their connexions.

were associated with mental dulness, others appear to have produced no symptoms during life and were only discovered accidentally in the post-mortem or dissecting room. Four cases of tumour involving the corpus callosum, three of which were primary, have been described by Bristowe, who believes that it may be possible to recognise the condition during the

life of the patient. The condition, like all cerebral tumours, is progressive; paralytic symptoms appear gradually, and paralysis of one side of the body is associated with vague hemiplegic symptoms on the other; a tendency to drowsiness and stupidity supervenes. At the same time, none of the cerebral nerves are directly involved, since none of them are in intimate relation with the corpus callosum.

Very little is known with regard to the functions of the large cortical areas which lie above and in front of the corpus callosum. This part of the medial surface is divided into upper and lower areas by the *sulcus cinguli* (*calloso-marginal fissure*), which ascends to the supero-medial border of the hemisphere a little in front of the splenium (Fig. 6). The upper area is termed the *marginal gyrus* and its posterior part is termed the *paracentral lobule*. The latter is usually cut into by the upper extremity of the central sulcus and it contains some of the higher motor centres for the lower limb of the opposite side (Fig. 6).

The **gyrus cinguli (callosal gyrus)** lies between the sulcus cinguli and the corpus callosum. When it is traced backwards it curves downwards and forwards round the splenium and becomes continuous with the **hippocampal gyrus** on the basal surface of the cerebrum. These two gyri together constitute the **gyrus fornicatus (limbic lobe)**.

Experimental and clinical evidence suggests that some of the *higher sensory centres* are situated in the gyrus cinguli, and lesions in this situation usually produce some alterations in sensibility on the opposite side of the body.

From the region of the occipital pole, the **Calcarine Fissure** passes forwards and meets the **Parieto-Occipital Fissure** at an acute angle below the splenium of the corpus callosum (Fig. 6). The area contained between these sulci and the supero-medial border of the hemisphere is known as the **Cuneus.** It belongs to the occipital lobe and contains some of the *higher visual centres.* A cortical lesion of the cuneus produces blindness in the lower lateral quadrant of the

retina of the same side and in the lower medial quadrant of the retina of the opposite side. This condition is known as *lower quadrantic hemianopia*. If, however, the lesion is confined to the area below the calcarine fissure, the upper

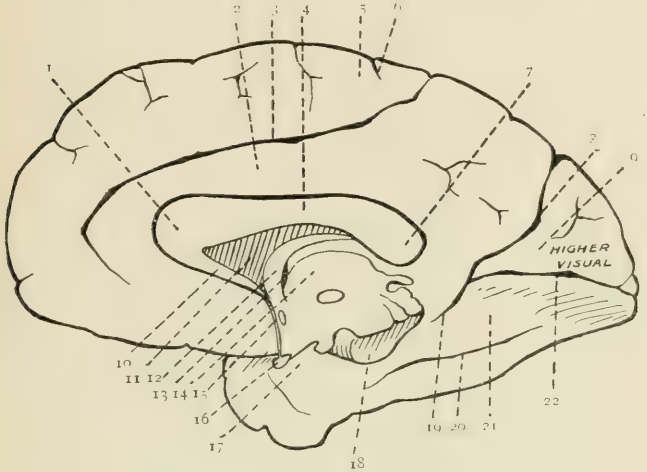


FIG. 6.—Medial Aspect of Right Cerebral Hemisphere.

1. Genu of corpus callosum.
2. Gyrus cinguli.
3. Sulcus cinguli (calloso-marginal).
4. Body of corpus callosum.
5. Motor centre for lower limb.
6. Central sulcus (of Rolando).
7. Splenium of corpus callosum.
8. Parieto-occipital fissure.
9. Cuneus.
10. Rostrum of corpus callosum.
11. Septum pellucidum.
12. Column of fornix.
13. Interventricular foramen (of Monro).
14. Thalamus.
15. Lamina terminalis.
16. Optic chiasma.
17. Uncus.
18. Cut surface of mid-brain.
19. Calcarine fissure.
20. Collateral fissure.
21. Lingual gyrus.
22. Calcarine fissure.

quadrants of the retinæ are affected. Finally, when the lesion involves both areas, homonymous hemianopia is the result (see p. 52).

The **Septum Pellucidum** is a bilaminar membrane which occupies the concavity of the genu of the corpus callosum

(Fig. 6), and serves to separate the anterior parts of the lateral ventricles from one another (Fig. 7). It is attached posteriorly to a flattened band of white fibres, termed the *fornix*, which, although separated in this way from the genu, is closely applied to the inferior surface of the body of the

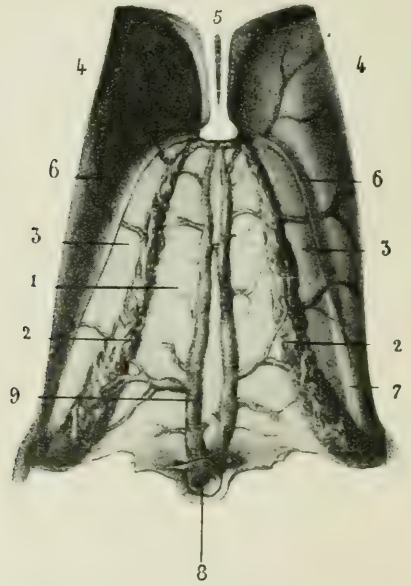


FIG. 7.—The Tela Chorioidea (velum interpositum) viewed from above.

1. Tela chorioidea.
2. Chorioid plexus.
3. Thalamus.
4. Caudate nucleus.
5. Septum pellucidum (cut).
6. Vein of corpus striatum.
7. Stria terminalis.
8. Great cerebral vein (of Galen).
9. Internal cerebral vein.

corpus callosum. The *column* (*anterior pillar*) of the fornix sinks into the substance of the medial surface of the brain as it descends to establish connexions with the *corpus mamillare* (p. 16).

The **Thalamus** is a large mass of grey matter which lies

below the fornix. Its free, medial surface (Fig. 5) forms the lateral wall of the third ventricle and is covered by ependyma, which can be traced downwards and backwards to the *cerebral aqueduct* (of Sylvius). The anterior extremity of the thalamus is separated from the column (anterior pillar) of the fornix by the **Interventricular Foramen (of Monro)**, through which the ependyma of the third ventricle passes to become continuous with the ependyma lining the lateral ventricle.

A fold of pia mater, termed the **tela chorioidea (velum interpositum)**, is carried into the interior of the brain below the splenium of the corpus callosum. It is situated between the inferior aspect of the fornix and the superior aspects of the thalami, and extends as far forwards as the interventricular foramen. In the median plane, the thalami are separated from one another by the third ventricle, the roof of which is formed by the tela chorioidea as it crosses from one side to the other. The large veins which return the blood from the substance of the brain are situated between the two layers of the tela chorioidea, and they emerge at its posterior edge between the splenium above and the dorsal aspect of the mid-brain below (Fig. 7).

In a median sagittal section of the brain, the mid-brain is divided immediately below the thalamus (Fig. 5). It is traversed, near its dorsal aspect, by the cerebral aqueduct (of Sylvius), which becomes greatly dilated behind the lower part of the pons and the upper part of the medulla oblongata, forming the *fourth ventricle.*

The Basal Surface of the Brain

The **Olfactory Tract** lies on the inferior aspect of the frontal lobe near the median plane. Its anterior extremity is enlarged to form the *olfactory bulb*, which is joined by the olfactory nerves from the mucous membrane of the nose. Congenital

absence of the olfactory nerves is one of the stated causes of *anosmia*.

The frontal lobes are separated from one another by the great longitudinal fissure. On the basal surface of the brain, the posterior part of this fissure is hidden by the *optic chiasma* (Fig. 8), from which the *optic nerves* arise anteriorly and the *optic tracts* posteriorly. The tracts pass backwards and laterally round the mid-brain to reach the lower visual centres (p. 51).

The **interpeduncular fossa** is bounded by the optic chiasma in front, by the mid-brain behind, and by the optic tract on each side. Its most anterior part is termed the *tuber cinereum* and it gives attachment to the *stalk of the hypophysis* (*pituitary body*). Behind the tuber cinereum lie the two *corpora mamillaria*, one on each side of the median plane. The *posterior perforated substance* occupies the posterior angle of the interpeduncular fossa.

The structures included in this area on the basal surface of the brain form the anterior part of the floor of the third ventricle, and this statement may be confirmed by reference to Fig. 5.

The **anterior perforated substance (ant. perf. spot)** lies lateral to the optic chiasma and forms the floor of the angle between the optic nerve and the optic tract. Its relationship to the internal carotid and the middle cerebral arteries is referred to on page 119. It may be noted that, whereas the posterior perforated substance lies in the median plane, the anterior perforated substance is bilateral. Both areas are pierced by small blood-vessels.

The *uncus* is a well-marked elevation which lies posteromedial to the temporal pole and lateral to the anterior perforated substance. It forms the anterior extremity of the hippocampal gyrus and so is part of the *gyrus fornicatus* (*limbic lobe*). It is said to contain the higher centres for the sense of smell.

On its lateral side, the hippocampal gyrus is bounded by the **collateral fissure**, which is separated from the calcarine

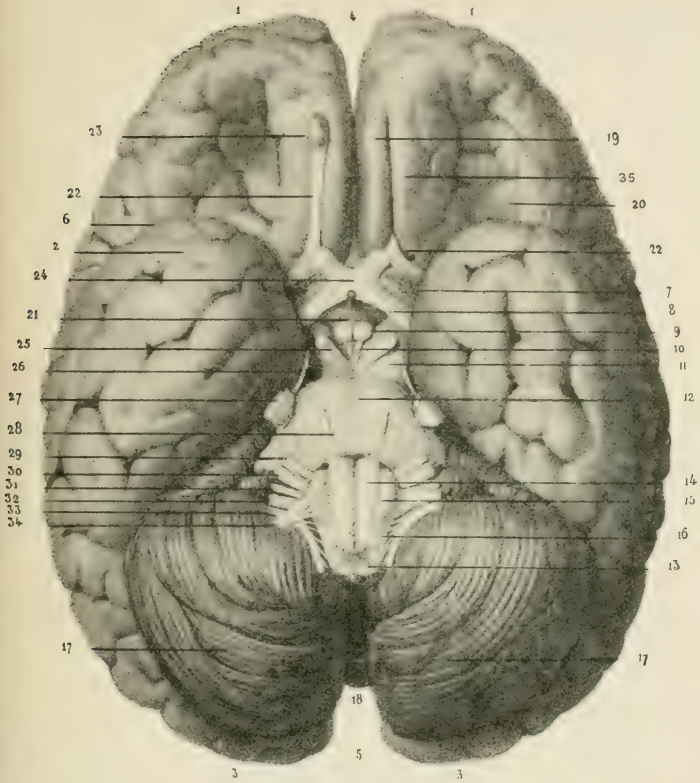


FIG. 8.—The Inferior Aspect of the Brain.

1. Frontal pole.
2. Temporal lobe.
3. Occipital pole.
4. Longitudinal fissure, anterior extremity.
5. Longitudinal fissure, posterior extremity.
6. Lat. fissure (of Sylvius).
7. Anterior perforated substance.
8. Optic tract.
9. Corpus mamillare.
10. Posterior perforated substance.
11. Cerebral peduncle (crus cerebri).
12. Pons.
13. Medulla oblongata.
14. Pyramid.
15. Olive.
16. Restiform body.
17. Cerebellar hemisphere.
18. Posterior cerebellar notch.
19. Gyrus rectus.
20. Orbital gyri.
21. Tuber cinereum.
22. Olfactory tract.
23. Olfactory bulb.
24. Optic chiasma.
25. Oculo-motor nerve.
26. Trochlear nerve.
27. Trigeminal nerve.
28. Abducent nerve.
29. Facial nerve.
30. Acoustic nerve.
31. Glosso-pharyngeal nerve.
32. Vagus nerve.
33. Accessory nerve.
34. Hypoglossal nerve.
35. Orbital gyri.

fissure posteriorly by the **lingual gyrus** (Fig. 9). The latter is believed by some authorities to contain the higher centres for the sense of taste.

The other cortical areas on the basal surface of the brain need not be specially described, since little is known with regard to the functions which they subserve.

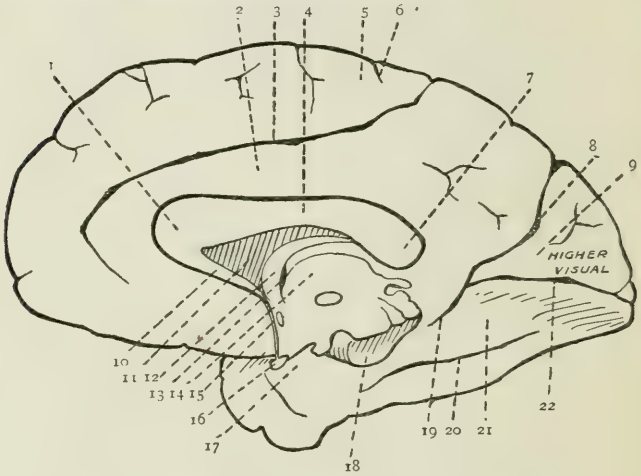


FIG. 9.—Medial Aspect of Right Cerebral Hemisphere.

17. Uncus.
19. Calcarine fissure.
20. Collateral fissure.
21. Lingual gyrus.

The **Mesencephalon or Mid-Brain**, which forms the uppermost part of the brain-stem, constitutes the connexion between the cerebral hemispheres and the pons. It consists of the four *corpora quadrigemina*, which lie on its dorsal aspect, and the *cerebral peduncles*, which are partially separated from one another anteriorly by a deep notch. The upper pair of the corpora quadrigemina are connected with the optic tracts (p. 51), while the lower pair are connected with the auditory tracts (p. 89). The cerebral peduncle consists of a dorsal part or *tegmentum*, which is continuous across the median plane, and a ventral part or *basis pedunculi* (*crusta*), which is

separated from the corresponding part by the notch above mentioned (Fig. 10). A small oval elevation, termed the

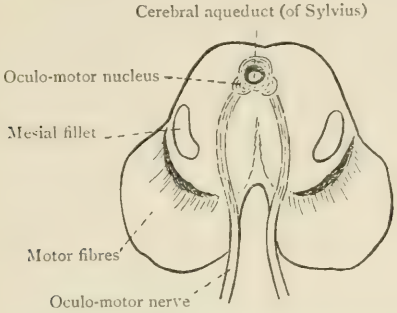


FIG. 10.—Transverse Section through the Mid-Brain, showing the dorsal portion, or tegmentum, which is separated from the ventral portion, or basis pedunculi, by the substantia nigra.

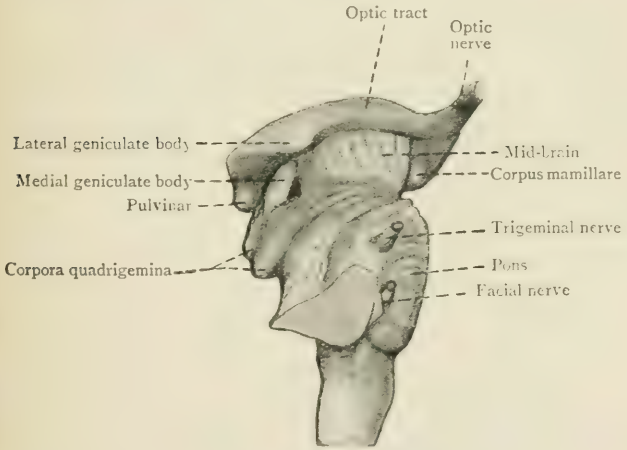


FIG. 11.—The Lateral Aspect of the Brain-Stem.

medial geniculate body, is placed on the lateral aspect of the cerebral peduncle and is partially overhung by the projecting posterior end of the thalamus (Fig. 11). It is connected

with the auditory tract, and the grey matter which it contains constitutes one of the lower auditory centres.

The *third* (*oculo-motor*) and *fourth* (*trochlear*) *cerebral nerves* emerge from the surface of the mid-brain. The former appears on the anterior aspect, but the latter leaves the dorsal aspect just below the inferior pair of corpora quadrigemina.

The **Pons** is interposed between the mid-brain above and the medulla oblongata below. Laterally, it is connected to

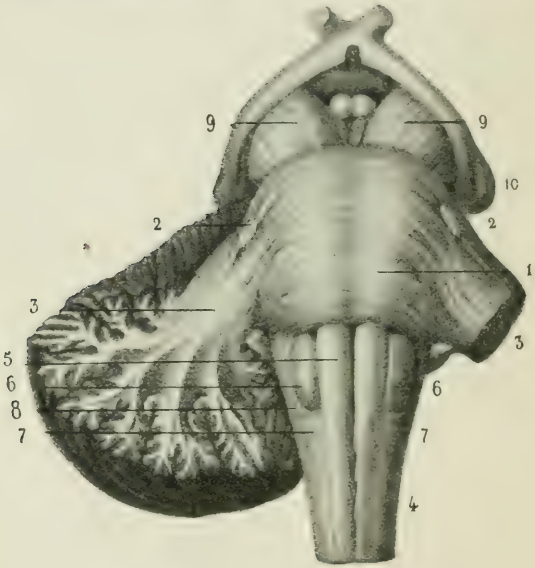


FIG. 12.—The Anterior Aspect of the Brain-Stem.

1. Pons.
2. Trigeminal nerve.
3. Brachium pontis.
4. Medulla oblongata.
5. Pyramid.
6. Olive.
7. Superficial arcuate fibres.
8. Restiform body.
9. Mid-brain.
10. Lateral geniculate body.

the cerebellar hemispheres by the *brachia pontis* (*middle cerebellar peduncles*). Its anterior surface bulges forwards and

presents a transversely striated appearance, which indicates the direction taken by its superficial fibres (Fig. 12). The dorsal surface of the pons forms the upper part of the floor of the fourth ventricle (Fig. 32).

The *fifth*, *sixth*, *seventh* and *eighth cerebral nerves* are all connected with the anterior surface of the pons. The fifth emerges from the brain-stem near the upper border of the pons, at its junction with the brachium pontis. The sixth emerges near the median plane, in the groove between the pons and the medulla oblongata. The seventh and eighth are connected to the same groove but lie farther away from the median plane (Fig. 8).

The **Medulla Oblongata** connects the pons above to the spinal medulla below. Its anterior surface is marked by two elongated elevations, which are termed the *pyramids*. They lie one on each side of the median plane and they are produced by the underlying pyramidal tracts. At a lower level the superficial part of the *decussation of the pyramids* can sometimes be made out in the median plane (Fig. 12). A second elevation is situated lateral to the pyramid and separated from it by a groove in which the fibres of the *twelfth* (*hypoglossal*) *nerve* emerge. It is termed the *olive*, and is produced by a mass of grey matter, known as the olivary nucleus. The *restiform body* forms a surface elevation on the lateral aspect of the medulla oblongata. It is separated from the olive by a longitudinal groove, in which the fibres of the *ninth*, *tenth* and *eleventh cerebral nerves* emerge from the brain-stem. (Fig. 8). Most of the tracts which constitute the restiform body pass upwards into the cerebellum.

The dorsal surface of the medulla oblongata in its upper part forms the lower portion of the floor of the fourth ventricle.

The **Cerebellum** lies in the posterior cranial fossa below the posterior parts of the cerebral hemispheres, from which it is

separated by a fold of dura mater, termed the tentorium cerebelli (p. 109). It consists of a narrow central portion, known as the *vermis*, and two *lateral hemispheres*. The cerebellum establishes connexions with the spinal medulla and the medulla oblongata by means of the *restiform bodies*, with the pons by means of the *brachia pontis* (*middle peduncles*), and with the mid-brain and cerebrum by the *brachia conjunctiva* (*superior peduncles*). The term "cerebello-pontine angle" is sometimes used to indicate the region where the brachium pontis enters the substance of the cerebellum (Fig. 12).

The cerebellum exercises a controlling influence over muscular tonus, and its cortex is intimately connected with the cortex of the motor area of the cerebrum. The latter, however, governs the muscles of the opposite side of the body, *whereas the cortex of the lateral cerebellar hemisphere is related to the homo-lateral muscles*. Cerebellar lesions are accompanied by inco-ordination and loss of equilibrating power and are typically characterised by a reeling, staggering gait. In the case of the cerebellum, as in the case of the brain, the symptoms are modified by the mode of onset of the lesion, and they are not so distinctive in slow-growing tumours as they are when the onset is more rapid. In the latter case, the patient tends to fall towards the side of the lesion, owing to the loss of tonus in the homo-lateral muscles, but in slowly progressing cases the patient learns to appreciate the tendency and often counteracts too strongly, so that he falls (or deviates in walking) to the opposite side.

Owing to the loss of tonus control, more work is thrown on the motor cortex of the cerebrum than it is able to perform efficiently. As a result, *intentional tremor* may be well-marked in cerebellar lesions.

In unilateral irritative lesions of the cerebellar cortex, cerebellar fits may occur. They are characterised by tonic spasms, most marked in the homo-lateral limbs.

In lesions of the vermis, retraction of the head and arching

of the back have been noticed, but the opposite movements have also been observed in similar cases.

The *blood-supply* of the cerebellum is derived from the basilar and the two vertebral arteries (p. 120). Cerebellar hæmorrhage, though not a common lesion, is of importance owing to the proximity of the fourth ventricle and the important centres in its floor (Fig. 5). The veins of the cerebellum terminate in the transverse (lateral) and other cranial blood-sinuses (p. 114). Septic infection may spread from the tympanic (mastoid) antrum, through the transverse sinus and cerebellar veins, and so give rise to abscess formation.

The Internal Structure of the Brain

The **Lateral Ventricles** of the brain are roofed in by the corpus callosum, which is covered on its inferior surface with ependyma. When the roof of the lateral ventricle is removed, the free surface of the *caudate nucleus* is exposed (Fig. 13). Its enlarged anterior extremity, or head, forms a prominent elevation in the anterior part of the floor of the ventricle, but, as it is traced backwards, it diminishes rapidly in size; at the same time, it arches upwards and laterally, so that, in a horizontal transverse section of the brain, the *head* of the caudate nucleus is cut through in front and the *tail* behind, but, owing to its upward bend, the *body* does not appear in the section (Fig. 18).

The superior surface of the *thalamus* lies in the floor of the ventricle to the medial side of the body of the caudate nucleus. It is overlapped by the free lateral margin of the *tela chorioidea* (*velum interpositum*) (p. 26), which contains the veins of the *chorioid plexus*. The serum which is transuded from the veins of this plexus through the ependyma into the lateral ventricle constitutes the *cerebro-spinal fluid*. This fluid circulates through the ventricular system and ultimately drains away into the subarachnoid space (p. 111). Excessive secretion

of the fluid is one of the causes of *hydrocephalus*, and, in this condition, the whole ventricular system may become enormously dilated.

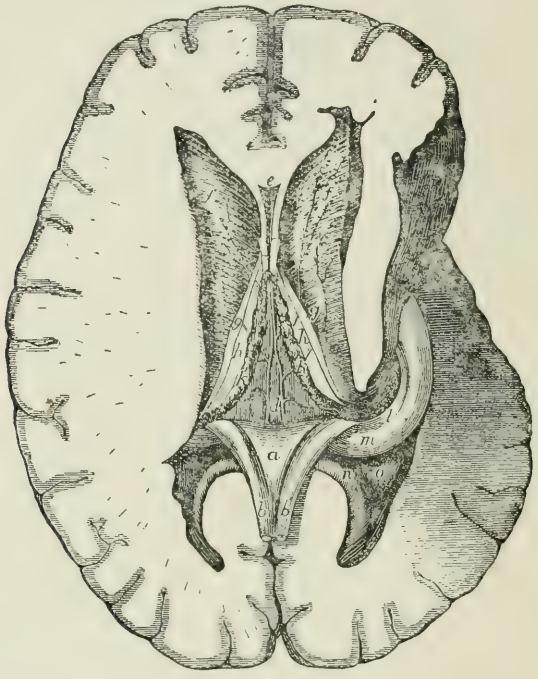


FIG. 13.—Dissection to show the Floor of the Lateral Ventricle. (TURNER'S *Anatomy*.)

The roof of the lateral ventricle has been removed, along with the greater part of the septum pellucidum. In addition the fornix has been divided and turned backwards, exposing the tela chorioidea (velum interpositum).

a. Fornix.
b, *c*. Columns of fornix.
d. Tela chorioidea
e. Corpus callosum, genu.
f. Caudate nucleus.
g. Stria terminalis (tænia semicircularis).
h. Thalamus.
i. Fimbria.
m. Hippocampus.
n Bulbus cornu.
o. Trigonum collaterale (ventriculi).

The tela chorioidea is itself overlapped by the free lateral edge of the **fornix**. The *body* of the fornix consists of

a flattened band of white fibres and its narrow anterior extremity divides into the two *columns* (*anterior pillars*) (p. 15). The posterior extremity of the fornix divides into two *crura*, which pass downwards and forwards in the floor of the inferior (descending) horn of the lateral ventricle to

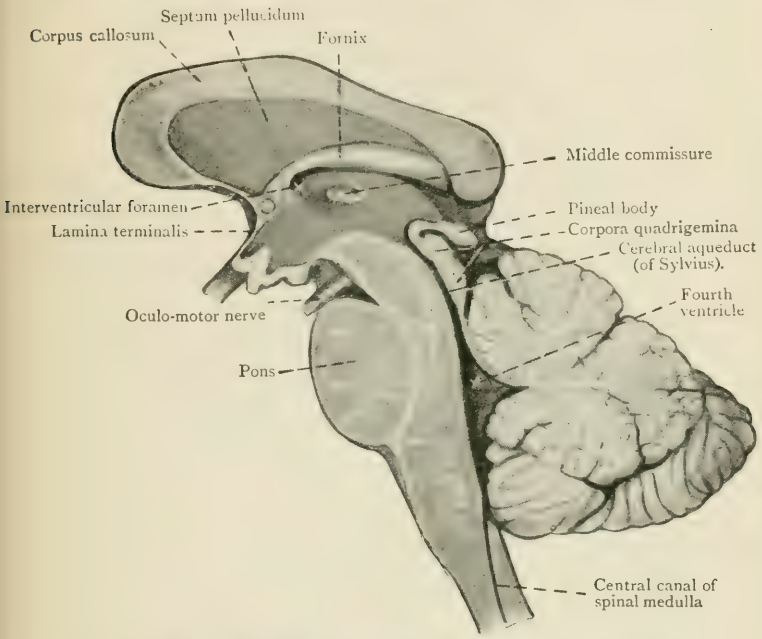


FIG. 14.—Median Sagittal Section through the Brain-Stem, showing the third and fourth ventricles and their connexions.

terminate in the uncus (p. 16). Superiorly, the fornix is attached to the septum pellucidum in front and to the corpus callosum behind (Fig. 14). Inferiorly, it is in contact with the tela chorioidea, which separates it from the superior surface of the thalamus on each side and from the third ventricle in the median plane.

The *medial wall* of the lateral ventricle is formed, anteriorly, by the septum pellucidum, and, posteriorly, by the union of the fornix with the corpus callosum. The *interventricular foramen* (*of Monro*), which connects the lateral with the third ventricle, is situated on this wall behind the column (anterior

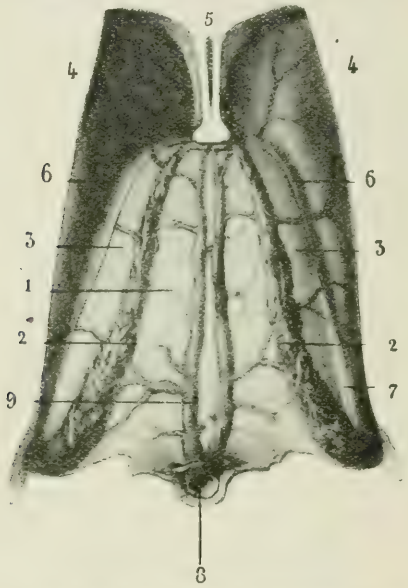


FIG. 15.—The Tela Chorioidea (velum interpositum) viewed from above.

1. Tela chorioidea.
2. Chorioid plexus.
3. Thalamus.
4. Caudate nucleus.
5. Septum pellucidum (cut).
6. Vein of corpus striatum.
7. Stria terminalis.
8. Great cerebral vein (of Galen).
9. Internal cerebral vein.

pillar) of the fornix and in front of the anterior extremity of the thalamus.

When the corpus callosum, the septum pellucidum, and the fornix are completely removed, the cavities of the two lateral ventricles are thrown into one and the **tela chorioidea (velum interpositum)** is exposed in its entirety (Fig. 13). It

is triangular in outline and its apex lies at the interventricular foramina. It extends from the one side of the median plane to the other and partially overlaps both thalami. In the median plane the tela chorioidea is stretched across the gap between the two thalami, and, in this situation, it forms the roof of the third ventricle. Between its two layers the *internal cerebral vein* (*of Galen*) passes backwards. It is formed at the interventricular foramen by the union of the vein of the corpus striatum (p. 29) with a vein from the chorioid plexus. At the posterior end of the tela chorioidea the two internal cerebral veins unite to form the *great cerebral vein* (*of Galen*) (Fig. 15), which emerges below the splenium of the corpus callosum and above the dorsal aspect of the mid-brain and terminates in the straight sinus.

Tumours of the cerebellum or of the corpora quadrigemina may obstruct the great cerebral vein near its termination (Fig. 55) and so produce engorgement of the veins of the chorioid plexus. As a result of this venous stasis, an increased amount of serum is transuded into the cerebral ventricles, giving rise to the condition of *acquired hydrocephalus.*

Prolongations of the lateral ventricle extend backwards into the occipital lobe and downwards into the temporal lobe and form, respectively, the *posterior* and the *inferior* (*descending*) *horns.*

The lateral ventricle may be *tapped* by passing in a special trochar and cannula at a point two fingers'-breadth in front of the mid-point of the line joining the glabella (p. 7) to the external occipital protuberance and about the same distance from the median plane (Fig. 16). The instrument is passed downwards and backwards for from $1\frac{1}{2}$ to 2 inches before it enters the ventricle (Kocher). The course taken by the instrument is planned so as to avoid the motor cortex and the middle frontal gyrus.

The inferior horn may also be reached from the surface without damage to the important cortical areas. The instrument is inserted at a point two fingers'-breadth behind the external acoustic meatus and the same distance above a line

drawn backwards from the lower border of the orbit through the centre of the external acoustic meatus (Fig. 16). It is directed medially and slightly upwards and forwards and passes below the higher auditory centres in the superior temporal gyrus. In the normal subject the inferior horn lies at a depth of

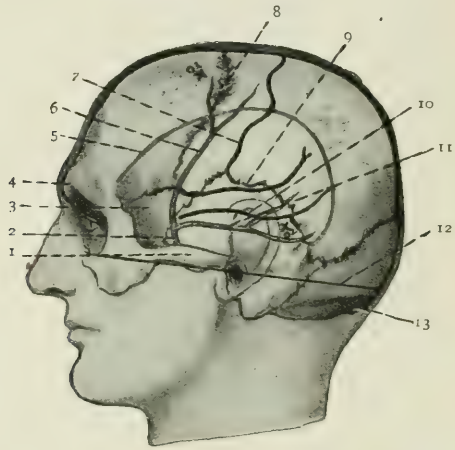


FIG. 16.—Lateral Aspect of Skull, showing the relations of important structures to the surface.

12. Line drawn from floor of orbit through centre of external acoustic meatus.
o^1. Site for puncture of lateral ventricle.
o^2 Site for puncture of inferior horn of lateral ventricle.

2 inches from the surface, but when the ventricles are distended, the brain substance may be greatly thinned out.

The **Third Ventricle** is situated in the median plane and its lateral walls are formed by the two thalami. Anteriorly, it is closed by the *lamina rostralis*, which extends from the rostrum of the corpus callosum to the optic chiasma (Fig. 6). This sheet of grey matter represents the anterior, or cephalic, extremity of the primitive neural tube (p. 2). The floor of the ventricle is formed by the structures which occupy the

interpeduncular fossa (p. 16) and, posteriorly, by the grooved upper surface of the mid-brain. The roof is formed by the tela chorioidea (velum interpositum) and, above that, by the fornix and the corpus callosum (Fig. 14).

The **Basal Ganglia** are masses of grey matter, which are more or less completely embedded in the substance of the brain near its basal surface. Their cells act as cell-stations for both afferent and efferent fibres of the cerebral cortex.

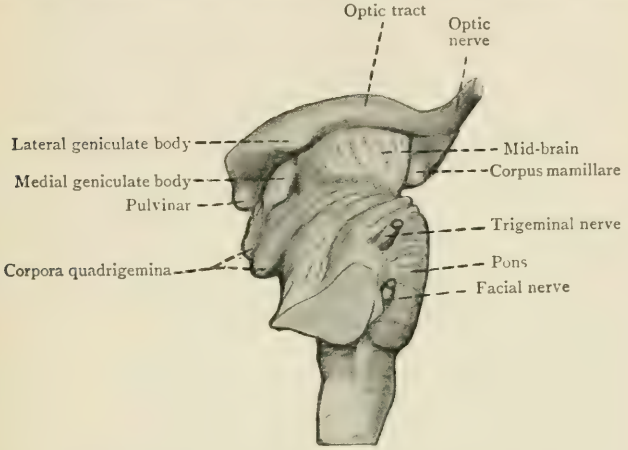


FIG. 17.—The Lateral aspect of the Brain-Stem.

The basal ganglia comprise (1) the thalamus, and (2) the corpus striatum, which is further subdivided into the caudate and the lentiform (lenticular) nuclei.

1. The **Thalamus** lies directly above, and is continuous with, one-half of the peduncle of the mid-brain, but projects beyond it both anteriorly and posteriorly. When viewed from above, it is seen to be somewhat triangular in outline and its postero-medial angle shows a distinct enlargement, which is termed the *pulvinar*. The postero-lateral angle, which overhangs the lateral aspect of the mid-brain, possesses

a similar elevation on its inferior surface. This elevation is termed the *lateral geniculate body*, and both it and the pulvinar receive afferent fibres from the optic tract (Fig. 17).

The superior surface of the thalamus has been mentioned (p. 23) in connexion with the floor of the lateral ventricle, and the medial surface in connexion with the lateral wall of the third ventricle (p. 28). Its lateral surface (Fig. 18) is in contact with the fibres of the internal capsule (p. 32). Owing to this latter relationship, the functions of the thalamus are extremely difficult to determine, as lesions are rarely restricted to the thalamus itself, and the possible involvement of the internal capsule cannot be excluded.

Lesions in the posterior part of the thalamus usually affect the pulvinar and the lateral geniculate body, and consequently produce homonymous hemianopia (p. 52). In addition, there is usually some degree of motor paralysis and of hemi-anæsthesia. Loss of deep sensibility is frequently co-existent with thalamic lesions and it is often accompanied by astereognosis and loss of muscle and joint sense. How far these symptoms are due to involvement of the internal capsule, it is at present impossible to determine.

2. The **Caudate Nucleus** (p. 23) and (3) the **Lentiform Nucleus** will be referred to in the description of the internal capsule (*vide infra*).

The precise functions of these nuclei are not yet understood. Bilateral lesions, *e.g.* progressive softening, of the lentiform nuclei cause difficulty in articulation and tremors and spasticity in the muscles of the trunk and lower limbs. Cases of this kind have been recorded in which careful examination has failed to detect any affection of the internal capsule.

Sections through the Brain

In **Horizontal Transverse Sections** made through the cerebral hemisphere at the level of the interventricular foramen, the island (of Reil) forms a conspicuous landmark.

It may be recognised as a submerged area of cerebral cortex, which is situated nearer to the frontal than to the occipital pole and is overlapped by the adjoining cortical areas (Fig.

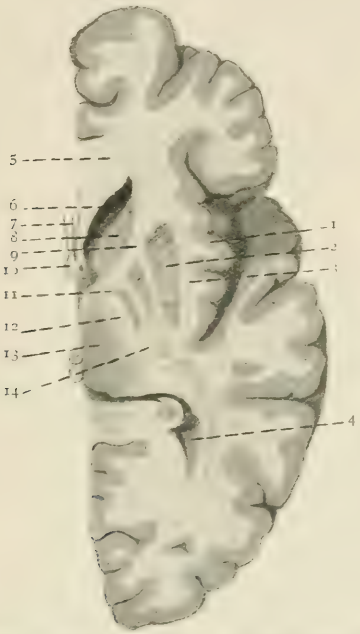


FIG. 18.—Horizontal Section through Left Cerebral Hemisphere.

1. Island (of Reil).
2. Lentiform nucleus.
3. Claustrum.
4. Posterior horn of lateral ventricle.
5. Corpus callosum.
6. Anterior horn of lateral ventricle.
7. Septum pellucidum.
8. Caudate nucleus.
9. Internal capsule, anterior limb.
10. Column of fornix.
11. Internal capsule, genu.
12. Internal capsule (motor fibres).
13. Thalamus.
14. Internal capsule (sensory fibres).

18). On the deep surface of the white matter of the island, and almost co-extensive with it, a thin sheet of grey matter is cut through. This is termed the *claustrum*, and it is separated from the lentiform nucleus by a narrow strip of white

matter, which is known as the *external capsule*. The *lentiform nucleus*, which resembles a biconvex lens in shape, is completely embedded in the substance of the cerebral hemisphere, and its medial surface is in contact with a broad band of white matter, termed the **internal capsule**. As seen in a horizontal section the internal capsule consists of two *limbs* which meet one another at a bend or *genu*. The shorter anterior limb lies between the lentiform nucleus and the head of the caudate nucleus, by which it is separated from the anterior part of the lateral ventricle; the longer, posterior

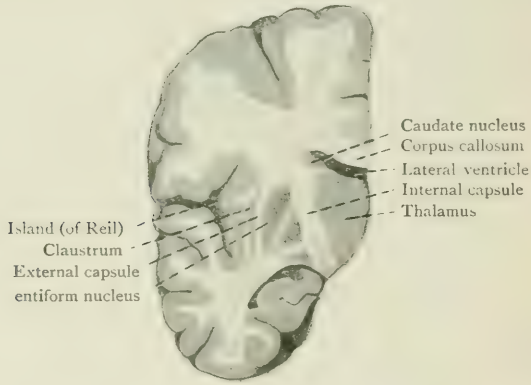


FIG. 19.—Frontal (Coronal) Section through Left Cerebral Hemisphere.

limb is closely applied to the lateral aspect of the thalamus (Fig. 18).

In a **Frontal (Coronal) Section** made through the cerebral hemisphere opposite the anterior perforated substance (spot), the island, the claustrum, and the external capsule can all be readily identified (Fig. 19). When the lentiform nucleus is examined in such a section, its lower part is seen to become continuous with the grey matter of the anterior perforated substance, and, consequently, the arteries which enter the brain at this point at once come into relationship with the

nucleus. The fibres of the internal capsule can be traced down from the cortex above into the ventral portion of the cerebral peduncle, and in their course they pass between the lentiform nucleus, on the lateral side, and the caudate nucleus and the thalamus, on the medial side. The arteries which supply the basal ganglia and the internal capsule arise from the middle cerebral (p. 119), as it lies below the anterior perforated substance, and they pass upwards over the lateral aspect of the lentiform nucleus. They bend medially and pierce the nucleus, giving it numerous branches. Thereafter they traverse the internal capsule and terminate on the caudate nucleus and the thalamus. The *artery of cerebral hæmorrhage* passes through the internal capsule a little behind the genu.

The **motor fibres**, which arise in the cortex of the anterior central gyrus, converge as they pass towards the internal capsule. And, at the same time, the fibres connected with the uppermost part of the gyrus incline backwards, while those connected with its lowermost part incline forwards. As a result, the motor fibres for the muscles of the tongue, face and head come to occupy the genu of the internal capsule, and lie in front of the fibres for the upper limb. Behind the fibres for the upper limb lie the motor fibres for the muscles of the trunk, while the fibres for the lower limb extend as far backwards as the middle of the posterior limb of the internal capsule.

In this part of the brain, therefore, all the motor fibres are crowded together in the genu and the anterior half of the posterior limb of the capsule, and it is probable that many sensory fibres accompany them. It must be remembered that all these fibres cross the median plane, either in the brain-stem or in the spinal medulla, before they reach their ultimate destinations, and that lesions of the internal capsule, therefore, produce their effects on the opposite side of the body. When the "artery of cerebral hæmorrhage" ruptures, the extravasated blood presses on the fibres in the anterior half of

the posterior limb of the capsule. Owing to the crowding together of the motor fibres, a very small hæmorrhage may be sufficient to cause complete hemiplegia, and, in addition, irregularly distributed areas of sensory disturbance. Clinical evidence shows that certain muscles very constantly remained unaffected or only slightly affected in lesions of the internal capsule. The diaphragm and other muscles of the trunk, and

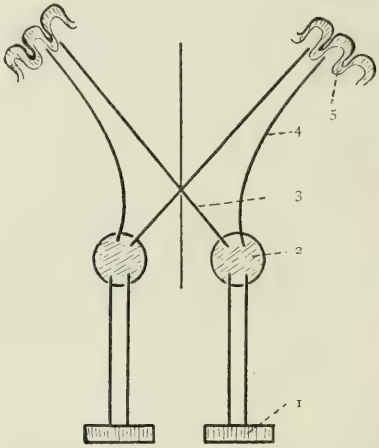


FIG. 20.—Diagram to illustrate Innervation of a Muscle by both Cerebral Hemispheres.

1. Muscle. 2. Motor nucleus. 3. Hetero-lateral upper neurone. 4. Homo-lateral upper neurone. 5. Cortex.

the muscles of the upper part of the face, are not paralysed. This immunity is explained on the grounds that muscles which are accustomed to act together are bilaterally represented in the cortex, and their motor fibres, therefore, descend in the internal capsules of both cerebral hemispheres (Broadbent's law). The same explanation accounts for the relatively smaller degree of paralysis in the lower limbs as compared with the upper limbs.

The anterior limb of the internal capsule is occupied chiefly by fibres which connect the cortex of the frontal lobe with the grey matter of the pons, and nothing is known concerning their function.

The posterior or retro-lenticular part of the posterior limb contains—(1) Sensory fibres from the opposite side of the body; (2) the acoustic radiation, which extends from the lower acoustic centres to the cortex of the superior temporal gyrus; (3) the optic radiation, which lies behind (1) and (2), extending from the lower visual centres (p. 51) to the occipital cortex. It is probable that the fibres of the other special senses, namely, taste and smell, also pass through the posterior third of the posterior limb of the internal capsule.

The manner in which the fibres of the internal capsule converge below and spread out above is well shown in Fig. 21, which represents a dissection carried out from the lateral aspect of the brain. The cortical areas which overlap the island (of Reil), the island itself, the claustrum, the external capsule and the lentiform nucleus have all been removed. The connexions of the capsule with the different parts of the cortex are clearly indicated, and it is evident that the lower the position of a lesion, the more complicated and widespread will be its effects.

A *lesion of the internal capsule* may be due to pressure, from tumour growth, hæmorrhage, etc., or to anæmia, following occlusion of the vessels of supply. When of large extent, it is accompanied by complete hemiplegia, hemi-anæsthesia, loss of muscle and joint sense, and deafness, all on the opposite side, and homonymous hemianopia affecting the corresponding sides of the retinæ. A smaller hæmorrhage may produce complete hemiplegia, with irregular sensory phenomena which are never confined to one limb.

A lesion of the postero-lateral part of the thalamus causes hemi-anæsthesia of the whole of the opposite half of the body. The condition is usually associated with disturbances of vision

or with motor paralysis which is most marked in the lower limb.

Lesions of limited extent in the region of the genu produce a condition which has been termed *pseudo-bulbar paralysis*,

FIG. 21.—Dissection of Brain, showing the Lateral Aspect of the Internal Capsule.

NOTE.—The overlying cortex, the claustrum, the external capsule and the lentiform nucleus have all been removed.

1. Internal capsule.
2. Corona radiata.
3. Optic radiation.
4. Anterior commissure.
5. Olfactory bulb.
6. Optic nerve.
7. Optic tract.
8. Uncus.
9. Temporal pole.
10. Mid-brain.
11. Oculo-motor nerves.
12. Trochlear nerve.
13. Pons.
14. Motor fibres in pons.
15. Pyramid.
16. Olive.

the fibres implicated being those destined for the tongue, palate, etc. It is said that this condition may be caused by unilateral lesions, but there is a disposition to believe that the lesion is bilateral or that, if unilateral, it is accompanied

by small lesions in the medulla oblongata (see *bulbar paralysis*, p. 108).

The **Path of the Motor Fibres.**—The motor fibres have already been traced from their origin in the anterior central gyrus, through an intermediate area termed the *corona radiata* (Fig. 21), into the internal capsule. Lesions of the corona radiata tend to resemble cortical lesions in their distribution, as, unless situated immediately above the internal capsule, they never produce complete hemiplegia (p. 6). Irritative lesions affecting the corona radiata alone differ from similar cortical conditions in that they cause tonic instead of clonic muscular spasms.

From the internal capsule, the motor fibres pass directly into the *basis pedunculi* (*crusta of the mid-brain*, Fig. 21), where they form a compact bundle, which is termed the *pyramidal tract.* At the lower border of the mid-brain, the pyramidal tract enters the ventral portion of the pons, and is there broken up into a number of small bundles by the grey matter and the transverse fibres of the pons. These separate bundles are reassembled below, and they descend through the ventral part of the medulla oblongata, forming the surface elevation which is termed the pyramid.

In the lower part of the medulla oblongata, the great majority of the fibres of the pyramidal tract pass backwards and cross the median plane. As they do so, they intersect the corresponding fibres of the opposite side, and the general arrangement is referred to as **the decussation of the pyramids.** These fibres, now known as the *lateral* or *crossed pyramidal tract*, descend in the lateral funiculus (column) of the spinal medulla and terminate by arborising round the cells of the posterior column (cornu) of grey matter. These cells send their fibres forwards to end round the cells of the anterior column, and these in turn give rise to the fibres which constitute the anterior roots of the spinal nerves. Thus, three neurones are concerned in the passage of stimuli from the cerebral cortex to the muscles.

Those fibres which do not take part in the decussation of the pyramids pass downwards in the anterior funiculus of the spinal medulla (Fig. 25), forming the *direct* or *anterior pyramidal tract.* It is probable that all these fibres cross the

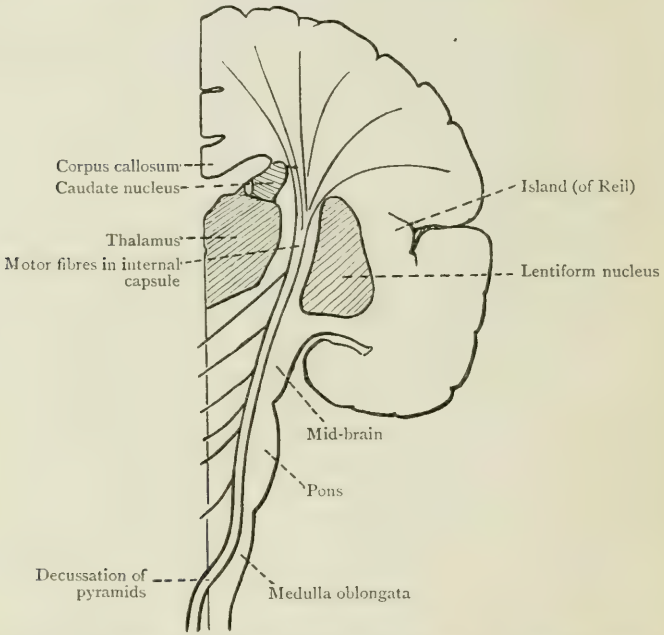


FIG. 22.—Diagram of Frontal (Coronal) Section of Right Cerebral Hemisphere and Brain-Stem, showing the path of the Motor Fibres.

In addition to the decussation of the pyramids, the numerous smaller decussations in connexion with the motor cerebral nerves are indicated in the diagram.

median plane at various levels in the spinal medulla and that they terminate in the same way as the fibres of the crossed pyramidal tract.

In addition to the decussations which have just been described, numerous smaller decussations occur at a higher level.

As the pyramidal tract passes down through the brain-stem, the fibres which are destined for the nuclei of the motor cerebral nerves leave it at different points and cross the median plane to reach their objective (Fig. 22). In doing so they decussate with the corresponding fibres of the opposite side. This arrangement, together with the fact that the pyramidal tract is placed at no great distance from the cerebral motor nuclei, offers an explanation for the occurrence of *crossed paralysis.*

The nucleus of the *third cerebral* (*oculo-motor*) *nerve* is placed in the mid-brain opposite the superior corpora quadrigemina, and the fibres which it obtains from the pyramidal tract decussate at a slightly higher level. If a small localised hæmorrhage occurs in the mid-brain at the level of the oculo-motor nucleus, it will involve the pyramidal tract *after* it has given off its fibres to the third nucleus of the opposite side. Such a hæmorrhage, however, may readily involve the oculo-motor nucleus on the same side, and a *crossed paralysis* results. The lower cerebral nerves and the spinal nerves are paralysed on the opposite side of the body, while the oculo-motor nerve is paralysed on the same side as the lesion. The oculo-motor nerve of the opposite side escapes because the lesion occurs *below* the point where its fibres leave the pyramidal tract and is not large enough to affect the structures in the opposite half of the mid-brain. This variety of crossed paralysis is sometimes referred to as the *syndrome of Weber.*

Theoretically, similar crossed paralyses may occur affecting any one of the motor cerebral nerves, but the only one of common occurrence is that in which facial paralysis exists on one side while the limbs are paralysed on the opposite side of the body. In this case, the lesion is placed in the pons at the level of the facial nucleus, and it is complicated by the fact that the nucleus of the sixth nerve and the sensory nucleus of the fifth are also likely to be involved (Fig. 23). The condition is described in detail on page 86.

The structure of the various parts of the brain-stem and the

results of lesions of the brain-stem will be dealt with when the nuclei of the individual cerebral nerves are described.

The **Spinal Medulla (Spinal Cord)** begins at the foramen magnum, where it is continuous with the medulla oblongata, and extends downwards through the vertebral canal to the lower border of the first lumbar vertebra. In the lower cervical and the lower thoracic regions, the spinal medulla

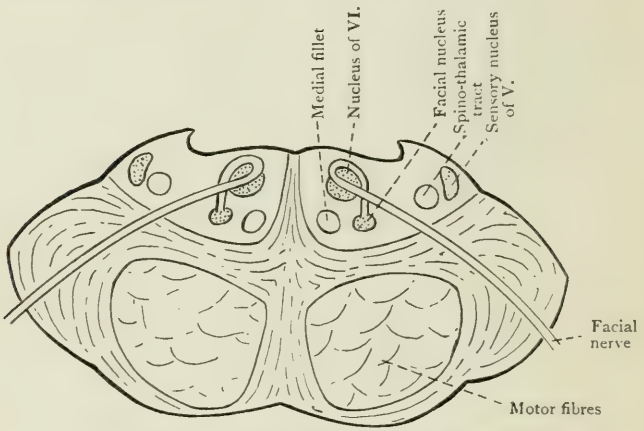


FIG. 23.—Transverse Section through the Pons (Diagrammatic).

increases in size, and these localised areas of enlargement correspond to the segments of origin of the great limb plexuses.

Owing to the relative disproportion in length between the spinal medulla and the vertebral canal, the nerve-roots must arise from the spinal medulla at a much higher level than the intervertebral foramina through which they pass. Below the lower end of the spinal medulla, therefore, the vertebral canal is occupied by the nerve-roots of the lumbar, sacral, and coccygeal nerves, which together constitute the *cauda equina*.

The lower lumbar region of the vertebral canal is selected as

the site for the operation of **lumbar puncture**, because (1) the site chosen should provide a free flow of the cerebro-spinal fluid; (2) there is no danger of injuring the delicate spinal medulla; (3) the spaces between contiguous laminæ is greatest in this region. There is little danger of injuring the nerve-roots of the cauda equina, as they tend to be pushed aside by the point of the needle.

The space between the fourth and fifth laminæ may be chosen, or the space between the fifth and the sacrum. Some authorities prefer to enter the needle in the posterior median line. In that case, the instrument passes between two consecutive spines instead of through the interlaminar interval. It must be remembered that the fourth lumbar vertebra lies on the line joining the highest points on the iliac crests. When the interlaminar interval between the fourth and fifth lumbar vertebræ is selected, the needle is inserted about half an inch below this line and rather less than one inch from the median plane, and it is thrust in a forward and slightly medial direction. If the point of the needle meets bone, it must be partially withdrawn and then re-inserted, after some alteration has been made in its direction. When the interlaminar interval is gained, the operator experiences the characteristic resistance due to the strong ligamentum flavum, which fills in the gap between the laminæ. In the adult, the instrument will require to be introduced to a depth of about two inches before it reaches the vertebral canal, but in the young child the distance is rather less than one inch.

In order to separate the laminæ as far as possible, the patient should lie on his side with the body fully flexed, while the operation is being carried out. If the interspinous interval is chosen, the needle must be directed forwards and slightly upwards, parallel to the inferior border of the spine. In this case, the strong supra-spinous ligament must first be pierced and the instrument then passes forwards through or by the side of the interspinous ligament, before it enters the canal.

After the needle has been successfully passed into the canal,

the dura mater must be traversed before any fluid can be obtained. Whether the fluid obtained is derived from the subdural or from the subarachnoid space seems to be immaterial.

Intracranial Tension.—Although it is impossible to determine the condition of the intracranial tension in the adult unless lumbar puncture is performed, it is quite easy to do so in the infant, owing to the presence of the *anterior fontanelle.*

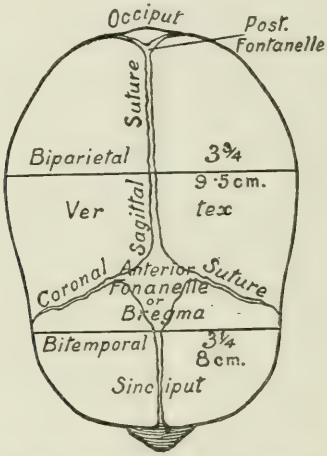


FIG. 24.—Fœtal Skull, seen from above. (JOHNSTONE'S *Midwifery.*)

This area is situated at the meeting-place of the two parietal bones with the two halves of the frontal bone, and it forms a diamond-shaped gap in the skull (Fig. 24). When the intracranial tension is normal, the bony edges of the fontanelle can readily be palpated and a normal slight pulsation, which is transmitted from the base of the brain, can be felt. This pulsation becomes more noticeable when the intracranial tension is slightly increased, but it disappears entirely when the tension is greatly increased and also when it is lowered.

Increased intracranial tension occurs in the acute fevers

and in cases of cerebral involvement, *e.g.*, the intracranial hæmorrhage of birth palsies. Cerebral symptoms induced reflexly by pathological conditions of other organs are not accompanied by any increase in intracranial tension.

Sinking of the anterior fontanelle indicates a *decrease in intracranial tension.* It marks a diminution of vitality, and is of common occurrence in epidemic enteritis and other conditions which are accompanied by a loss of fluid from the body.

The anterior fontanelle should be closed by the end of the second year. Delayed closure occurs in certain constitutional diseases, *e.g.* rickets, cretinism, etc., or it may be due to hydrocephalus or some other condition causing increased intracranial tension. If the anterior fontanelle closes too early, the condition of microcephalus results.

The **Structure of the Spinal Medulla** is identical with the structure of the brain, but the arrangement of its constituent parts is somewhat different. The grey matter is situated centrally and consists of *anterior* and *posterior columns* (*horns*); the white matter, which consists of afferent and efferent tracts, completely surrounds the grey matter (Fig. 25).

The *posterior funiculus* (*columns of Goll and Burdach*) of the spinal medulla lies between the posterior column of grey matter and the middle line. It contains a few tactile fibres and the fibres which convey *joint and muscle sense.* These latter arise in the nerve-cells in the ganglia on the posterior nerve-roots of the spinal nerves and ascend, through the spinal medulla, to the medulla oblongata, where they establish connexions with the cerebellum. Above the level of the decussation of the pyramids, they cross the median plane and ascend through the pons and mid-brain to reach the thalamus. Their precise destination is not yet known, but they probably traverse the posterior part of the posterior limb of the internal capsule.

In advanced cases of locomotor ataxia, joint-sense and

muscle-sense are both entirely lost, and, on post-mortem examination, the posterior funiculi are found to have undergone complete degeneration.

The *lateral funiculus* (*column*) lies to the lateral side of the columns of grey matter and contains, among others, the *lateral pyramidal* and the *spino-thalamic tracts*. The former, which undergoes decussation in the lower part of the medulla oblongata (p. 37), is distributed ultimately to the muscles of

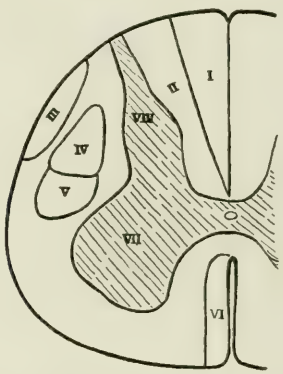


FIG. 25.—Transverse Section through Spinal Medulla (Schematic).

I, II. Muscle and joint sense.
III. Equilibration sense.
IV. Motor tract (crossed).
V. Painful, tactile and thermal sensibility.
VI. Motor tract (uncrossed).
VII. Anterior column of grey matter.
VIII. Posterior column of grey matter.

the same side of the body. The spino-thalamic tract is made up of the afferent fibres which convey *painful*, *thermal* and *tactile sensations*. These fibres enter the spinal medulla in the posterior nerve-roots and at once cross the middle line in the neighbourhood of the central canal (Fig. 26). They then ascend in the lateral funiculus to reach the thalamus and the posterior limb of the internal capsule, but little is known with reference to the cortical areas with which they are associated (p. 12). As the spino-thalamic tract passes up-

wards, it increases in size owing to the accession of new fibres. In the medulla oblongata and the pons, it receives fibres from the sensory nuclei of the cerebral nerves of the opposite side.

Lesions in the medulla oblongata may affect the spino-thalamic tract together with one of the sensory cerebral nuclei, the fifth being most frequently involved (p. 61). The resulting condition is akin to crossed paralysis (p. 39) and is termed *alternate hemianæsthesia*, because the anæsthesia affects the

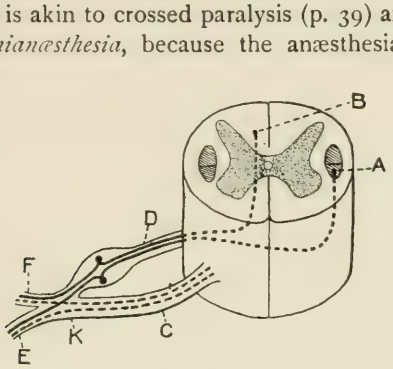


FIG. 26.—Diagram to illustrate the course taken by Sensory Fibres after entering the Spinal Medulla.

A. Spino-thalamic tract (painful, thermal and tactile sensations).
B. Posterior funiculus of spinal medulla (muscle and joint sense, and a few tactile fibres).
C. Anterior nerve-root.
D. Posterior nerve-root.
E. Anterior ramus (primary division).
F. Posterior ramus.
K. Typical spinal nerve.

limbs of the opposite side and the trigeminal nerve on the same side as the lesion.

In a **Hemi-lesion of the Spinal Medulla** in the mid-thoracic region, the lower limb of the same side is completely paralysed owing to the interruption of the lateral pyramidal tract, and, since it is the upper neurone which is affected, the paralysed muscles are spastic. In addition, there is loss of muscular and joint sense in the paralysed limb, since the fibres which convey these varieties of sensibility do not decussate until they reach the medulla oblongata. On the other hand, the

conduction of painful, thermal and tactile sensations from the paralysed limb is not interfered with, since these fibres cross the median plane as soon as they enter the spinal medulla. The lower limb of the opposite side is not paralysed, but, since the spino-thalamic tract is involved, it is rendered completely anæsthetic to painful and thermal sensations and partially anæsthetic to tactile stimuli. Muscle sense, however, is unimpaired on the unparalysed side.

Owing to the difference in length between the spinal medulla and the vertebral canal (p. 40), the upper limit of the anæsthetic area is considerably lower than the actual level of the lesion. At the level of the upper limit of anæsthesia, but on the paralysed side of the body, there is a narrow zone of complete anæsthesia. This condition is due to injury of the sensory fibres as they enter the spinal medulla, and it affects the same side as the lesion, since the fibres are implicated before they cross the middle line.

The crossed motor and sensory paralysis which results from a hemi-lesion of the spinal medulla is known as *Brown-Séquard Paralysis.*

In **Acute Anterior Poliomyelitis** the lesion is confined to the anterior column of the grey matter of the spinal medulla and it consequently produces a purely motor paralysis. Further, it is usually restricted either to the cervical or the lumbar enlargement of the spinal medulla, but, in severe cases, it may be more widespread. The areas of grey matter affected by the lesion are identical with the areas supplied by the anterior spinal arteries, and it is believed that the organism which produces the disease reaches its destination by the blood-stream.

Many of the muscles which are paralysed in the acute stage completely recover at a later period. The residual paralysis is of the lower neurone type (p. 3). Consequently, the paralysed muscles are flaccid; they undergo atrophy and their electrical reactions become altered.

In **Progressive Muscular Atrophy** the lesion may commence

in the motor tract and spread to the anterior column of grey matter in the spinal medulla, or it may commence in the anterior column and spread to the motor tract. In the first case, the initial symptoms are those of an upper neurone affection (p. 3), whereas in the second case they belong to the lower neurone type (p. 3).

The lesion usually commences in the first thoracic segment of the spinal medulla, and, in consequence, the small muscles of the hand (p. 156) are the first to undergo atrophic changes. The disease gradually spreads upwards and downwards along the spinal medulla, and the muscles of the forearm, arm and trunk become similarly affected. The sterno-mastoid and the upper part of the trapezius (accessory nerve, p. 103) are attacked late in the disease, and their involvement indicates that the lesion is spreading to the medulla oblongata, where it affects the nuclei of the ninth, tenth, eleventh and twelfth cerebral nerves, causing *bulbar paralysis* (p. 108). It should be noted that the muscles of the face and the platysma, which are supplied by the facial nerve, are practically never involved.

In **Syringomyelia** the lesion is situated near the base of the posterior column (cornu) of the grey matter. The cells in which the fibres of the pyramidal tract end (p. 37) may be affected, but the most characteristic symptoms are due to interference with the sensory path. Thermal and painful sensations are lost, since the fibres are interrupted as they traverse the grey matter to reach the other side of the spinal medulla. Tactile sensation, as a rule, is not affected, because many of the tactile fibres ascend in the posterior columns, without first crossing the median plane (p. 43). The motor paralysis is always of the upper neurone type (p. 3), since the cells in the anterior column (cornu) are not involved.

Complete Transverse Lesions of the spinal medulla necessarily produce both motor and sensory paralysis. If the lesion is placed in the thoracic region, spastic paraplegia results, although the paralysed muscles may be flaccid, in the case of

transverse myelitis, when the disease affects the grey matter in the lumbar region. The paralysed limbs are completely anæsthetic and there is loss of joint and muscle sense. In most cases, since the micturition centre in the hypogastric plexus (p. 373) is cut off from its central connexions, there is at first retention of urine, but the lower centre soon adapts itself to the altered conditions and thereafter the act of micturition becomes automatic.

A complete transverse lesion in the lower cervical region produces similar, but more widely spread, sensory and motor paralyses. In addition, the symptoms are complicated by complete interruption of the connexions between the sympathetic system and the spinal medulla (p. 186).

It may sometimes be difficult to determine whether a case of spastic paraplegia is functional or organic in origin. If the patient is placed in the dorsal decubitus and one limb is passively lifted, the position assumed by the opposite limb is a valuable guide. When the condition is organic, the muscular rigidity causes the pelvis to become tilted, and this movement of the pelvis causes the limb to be elevated slightly from the bed.

When the spinal medulla is gradually compressed, *e.g.* in inflammation of the meninges or vertebral caries, motor paralysis is the first sign of nervous complications. As the disease progresses, subjective sensory phenomena occur and they are accompanied by hyperæsthesia. In the later stages, there is complete motor and sensory paralysis.

THE CEREBRAL NERVES

The **First** or **Olfactory Nerve** is represented by a number of small branches which arise from the inferior aspect of the olfactory bulb. They at once pass downwards through foramina in the lamina cribrosa of the ethmoid (Fig. 27) and gain the interior of the nose, where they are distributed to the mucous membrane of the septum and of the lateral wall.

Fractures of the anterior cranial fossa may injure either the olfactory bulbs or nerves and give rise to anosmia. The olfactory nerves are restricted to the uppermost parts of the nasal fossæ, and these areas are rarely reached by local

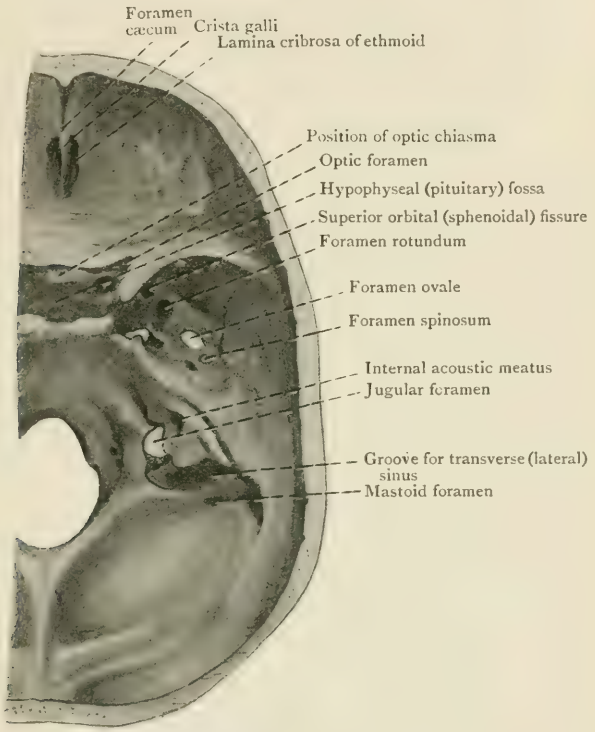


FIG. 27.—Floor of Skull.

anæsthetics. Consequently, although cauterisation of the mucous membrane of the inferior meatus of the nose may be carried out quite painlessly under local anæsthesia, the patient is acutely conscious of the disagreeable odour of the charred tissue.

Centrally, the olfactory nerves are connected through the olfactory bulb and tract with the fornix and the uncus. Existing knowledge is by no means definite with regard to these connexions and the symptom of anosmia is of little value, therefore, for topical diagnosis.

The **Second** or **Optic Nerve** arises in the cells of the retina and, passing backwards and medially (p. 16), leaves the

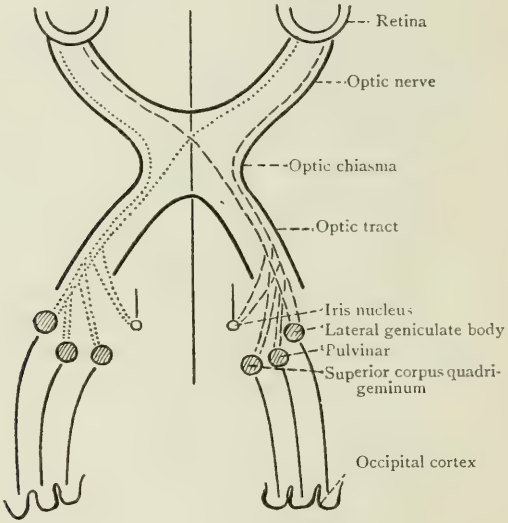


FIG. 28.—Diagram of course of Visual and Pupillary Fibres.

orbit through the optic foramen to reach the **optic chiasma** (Fig. 8). Lesions of the optic nerve will, according to their degree of severity, cause partial or complete blindness in the eye of the same side.

The fibres which arise from the nasal side of the retina decussate at the optic chiasma and then pass backwards along the *optic tract* of the opposite side. The fibres from the temporal side of the retina do not decussate, but enter the

optic tract of the same side. Each optic tract contains, therefore, fibres arising from the temporal half of the retina of its own side and fibres arising from the nasal half of the retina of the opposite side (Fig. 28).

The **optic tract** passes backwards and laterally round the lateral side of the cerebral peduncle and its fibres terminate in the **lower visual centres** These consist of—(1) The *pulvinar* of the thalamus (p. 29); (2) the *lateral geniculate body* (p. 30); and (3) the *superior corpora quadrigemina* (p. 18).

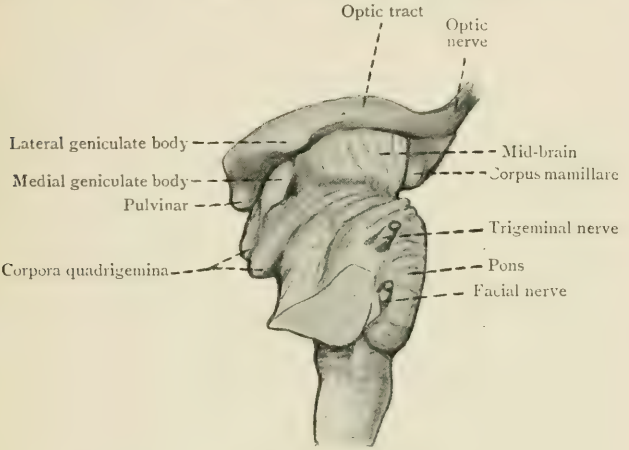


FIG. 29.—The Lateral Aspect of the Brain-Stem.

From the cells in the lower visual centres there arise new fibres which at once enter the retro-lenticular part of the posterior limb of the internal capsule, where they are related anteriorly to the acoustic and other sensory fibres. They then pass backwards into the occipital lobe and terminate in the cortex on its lateral and medial aspects. Those fibres which arise in the lower quadrant of the retina are connected with the upper portion of the occipital cortex, while those from the upper quadrant of the retina are connected with the lower portion (p. 13). The lower visual

centres also establish communications with the nuclei of other cerebral nerves.

Two neurones, therefore, are concerned in the transference of stimuli from the retina to the cortex. Lesions which affect either the higher neurone or the lower neurone behind the optic chiasma produce exactly similar results. The temporal half of the homo-lateral retina (nasal side of the field of vision) and the nasal half of the hetero-lateral retina (temporal side of the field of vision) are both blind. Whether the lesion affects the upper or the lower neurone can be determined by the test for *Wernicke's sign.*

Under normal conditions when a strong ray of light stimulates the retina, both pupils become contracted. This is known as the *light reflex*, and it is believed that a special set of fibres is concerned in its production. These *pupillary fibres* leave the retina in the optic nerve, and at the optic chiasma they undergo a decussation which is precisely similar to the partial decussation of the visual fibres. They then pass backwards in the optic tract, but do not terminate in the lower visual centres. Instead, they terminate in the *iris nucleus*, which is a special collection of cells in the nucleus of the oculo-motor nerve.

In **Wernicke's test**, a ray of light is reflected on to the blind half of the retina and, as the test is extremely delicate, great care must be taken to ensure that the light does not impinge on the unaffected part of the retina. *When the upper neurone is the site of the lesion*, the light stimulus is not interrupted in its passage to the iris nucleus and the light reflex is present, so that in this condition Wernicke's sign is positive. *In affections of the lower neurone*, the pupillary fibres may escape when the lesion is situated in the lower visual centres. On the other hand, when the lesion involves the optic tract, the pupillary fibres are affected to the same extent as the visual fibres, and just as the visual stimulus is cut off from the lower centres, causing homonymous hemianopia, so Wernicke's test applied to the blind halves of the retinæ gives a negative result.

Additional signs may be present and may help in the localisation of lesions producing homonymous hemianopia. Lesions affecting the optic tract are likely to cause some motor paralysis or paresis. The third and fourth cerebral nerves, owing to their proximity, may be involved, while the

FIG. 30.—Dissection of Brain, showing the Lateral Aspect of the Internal Capsule.

1. Internal capsule. 6. Optic nerve. 7. Optic tract. 10. Mid-brain.

lesion may affect the pyramidal tract, as it descends in the mid-brain in close relation to the optic tract (Fig. 30).

When the upper neurone fibres are affected in the internal capsule, the adjoining acoustic and sensory fibres (p. 35) are likely to be involved, causing the occurrence of deafness and of irregularly distributed areas of anæsthesia on the opposite

side of the body. The condition of quadrantic hemianopia in lesions of the occipital cortex has already been described (p. 13).

The effects which result from pressure on the optic chiasma are by no means constant. Homonymous or heteronymous hemianopia or complete blindness in one or both eyes may occur. Bitemporal hemianopia occurs in many cases of acromegaly, and it is due to pressure on the optic chiasma by tumours of the hypophysis (pituitary body), which is related to its posterior aspect (p. 401).

The optic chiasma, the posterior ends of the optic nerves, and the anterior ends of the optic tracts are all situated in the cisterna interpeduncularis (p. 111). On this account they are often involved in basal meningitis, and the ensuing symptoms may be very irregular.

The "Argyll-Robertson pupil," which is an important early symptom of locomotor ataxia, consists in the loss of the light reflex, although the pupillary reactions to convergence and accommodation remain normal. Since vision is not affected, it is not improbable that the condition may be caused by a lesion affecting the pupillary fibres, after they leave the optic tract and before they reach the iris nucleus (Fig. 28).

The THIRD or OCULO-MOTOR, the FOURTH or TROCHLEAR, and the SIXTH or ABDUCENT NERVES are all purely motor in function, and their distribution is restricted to the muscles of the orbit and of the eyeball.

NOTE.—It is convenient to describe the course and relations of these nerves and to indicate the actions of the orbital muscles, before the distribution of the nerves and the results of pathological lesions are dealt with.

The **Oculo-motor Nerve** arises from a nucleus which is placed in the upper part of the mid-brain in the grey matter which surrounds the cerebral aqueduct (Fig. 10). From the nucleus the fibres pass forwards through the mid-brain and emerge on its anterior surface. The nerve traverses the cisterna basalis and pierces the dura mater to the lateral side of

the dorsum sellæ of the sphenoid (Fig. 35). The next part of its course is situated in the lateral wall of the cavernous sinus (p. 115) between the supporting dura mater and the endothelial lining (Fig. 31), where it is closely related to the fourth and sixth nerves. It is here placed lateral to the hypophysis (pituitary body), but is separated from it by the internal carotid artery and the sinus itself. On leaving the anterior end of the cavernous sinus, the oculo-motor nerve

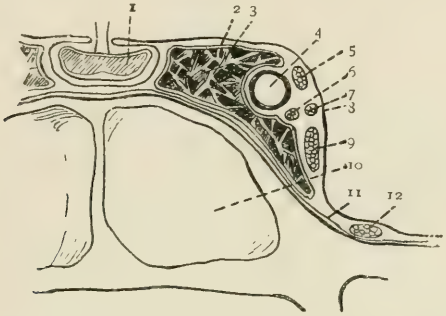


FIG. 31.—Transverse Section through the Cavernous Sinus.

1. Hypophysis.
2. Endothelial wall of sinus.
3. Cavernous sinus.
4. Internal carotid artery.
5. Oculo-motor nerve.
6. Abducent nerve.
7. Trochlear nerve.
8. Serous layer of dura mater.
9. Ophthalmic nerve.
10. Sphenoidal air-sinus.
11. Endo-periosteum of skull.
12. Maxillary nerve.

enters the orbit through the superior orbital (sphenoidal) fissure.

The **Trochlear Nerve** has its nucleus in the lower part of the mid-brain. The emerging fibres pass backwards and medially from their origin and, crossing the median plane, leave the posterior surface of the mid-brain immediately below the inferior corpora quadrigemina. The trochlear nerve is exceptional, therefore, in two ways :—(1) It arises from the dorsal aspect of the brain-stem, and (2) its fibres decussate *after* they leave the nucleus. Thereafter, the nerve winds

round the lateral aspect of the mid-brain and enters the cisterna basalis. It passes forwards parallel to but below the oculo-motor nerve and, after running in the lateral wall of the cavernous sinus, enters the orbit through the superior orbital fissure. Its relations are practically the same as those described for the oculo-motor nerve.

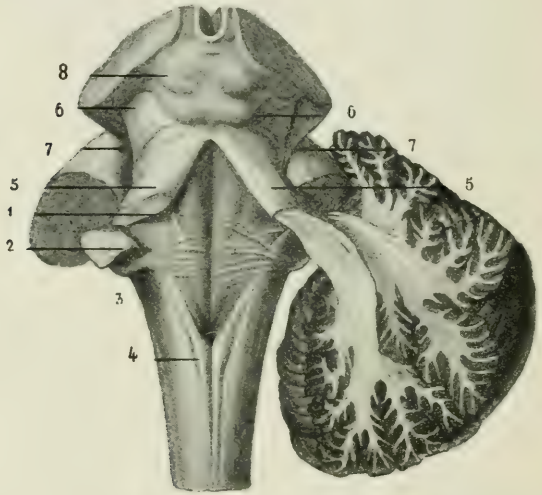


FIG. 32.—The Posterior Aspect of the Brain-Stem. The left half of the Cerebellum has been removed and the right half has been displaced to the right side.

1. Fourth ventricle.
2. Restiform body.
3. Medulla oblongata.
4. Clava.
5. Brachium conjunctivum.
6. Mid-brain.
7. Brachium pontis.
8. Superior corpus quadrigeminum.

The **Abducent Nerve** arises from a nucleus which is situated in the lower part of the pons, immediately under the floor of the fourth ventricle (Fig. 23). This nucleus is intimately related to the fibres of the seventh nerve and, consequently, lesions of the sixth nucleus are often associated with some degree of facial paralysis. From its origin, the

sixth nerve passes forwards through the pons and emerges at its lower border, near the median plane. Its subsequent course is similar to that taken by the third nerve. Having crossed the cisterna basalis, it passes through the lateral wall of the cavernous sinus and gains the orbit through the superior orbital fissure.

The **Muscles of the Orbit.**—The *levator palpebræ superioris* acts as an elevator of the upper eyelid and is therefore antagonistic to the *orbicularis oculi* (*palpebrarum*) (p. 82). When the latter muscle is involved in facial paralysis, the increased tonus of the unopposed levator keeps the eye constantly open. During sleep, however, the levator relaxes and the eye may become almost completely closed. The levator palpebræ superioris is supplied by the third nerve and, when it is paralysed, the condition of *ptosis* results (cf. pseudo-ptosis, p. 210).

The *superior rectus* passes forwards from the posterior part of the orbit and is inserted into the sclerotic coat a little in front of the equator. It lies above the eyeball and consequently acts as an upward rotator. The pull of the superior rectus, however, does not impart a pure upward movement to the pupil, but it adds a slight medial deviation as well.

The superior rectus acts in concert with the *inferior oblique*, which arises from the antero-medial part of the floor of the orbit and passes laterally and backwards to be inserted into the sclerotic behind the equator. It rotates the eyeball so as to make the pupil look upwards and laterally.

When these two muscles act together, they produce a pure upward movement, since the medial pull of the superior rectus is counterbalanced by the lateral pull of the inferior oblique. Both are supplied by the oculo-motor nerve.

The attachments of the *inferior rectus* are simliar to those of the superior rectus, but the former muscle is applied to the inferior aspect of the eyeball so that it acts chiefly as a downward rotator. As in the case of the superior rectus, the

principal movement is complicated by a deviation medially. This is counter-balanced by the action of the *superior oblique*, which, acting through a fibrous pulley (Fig. 33), rotates the eye so as to make the pupil look downwards and laterally. Pure downward rotation is obtained when the two muscles act together. The inferior rectus is supplied by the third and the superior oblique by the fourth cerebral nerve.

The *lateral* and the *medial recti* are applied, respectively, to the lateral and the medial aspects of the eyeball. The former is a pure abductor of the eye, *i.e.*, it rotates the eyeball so as to make the pupil look laterally. It is supplied by the abducent nerve. The medial rectus rotates the eyeball in the opposite direction. Its nerve-supply is derived from the oculo-motor.

The *intrinsic muscles* of the eye are supplied directly from the *ciliary ganglion* (p. 66). The sphincter of the pupil and the ciliary muscle (the muscle of accommodation) are innervated primarily from the oculo-motor nerve, while the dilator of the pupil gains its supply from the sympathetic system (p. 187).

Paralysis of the Orbital Muscles

The third, fourth and sixth cerebral nerves are frequently all affected by the same lesion, since they follow the same intra-cranial course after they emerge from the brain-stem, and their upper neurones are closely related in the internal capsule, the corona radiata and the cortex.

Supra-nuclear Lesions, unless they are bilateral, rarely produce complete paralysis of any of the muscles of the orbit. Under normal conditions, the movements of the two eyes are always associated. Thus, except in the comparatively rare movement of convergence, the lateral rectus always works in association with the medial rectus of the opposite side. In order that perfect harmony may be obtained, both these muscles are bilaterally represented in the cortex. The arrangement is illustrated in Fig. 20, where it is seen that each nucleus receives fibres from the cortex on both sides. Further,

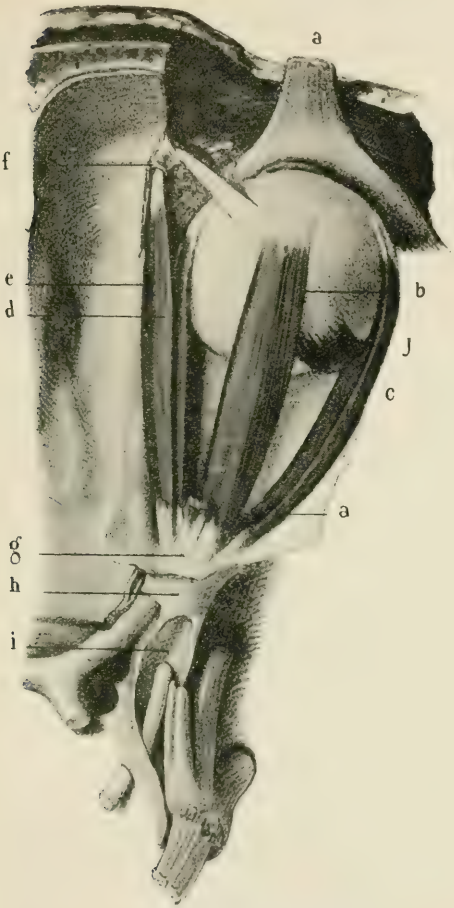


FIG. 33.—The Muscles of the Orbit.

a. Levator palpebræ superioris, divided and turned forwards.
b. Superior rectus.
c. Lateral rectus.
d. Superior oblique.
e. Orbital periosteum.
f. Pulley of superior oblique.
g. Origin of muscles of orbit.
h. Orbital periosteum.
i. Medial end of superior orbital (sphenoidal) fissure.
j. Inferior oblique.

those fibres which come from the same side arise in the group of cells which are ultimately connected with the associated muscle of the opposite side.

Nuclear Lesions may be single and they may only involve a part of the nucleus. The oculo-motor nucleus contains numerous cell-groups, each reserved for one of the muscles supplied. On this account, one or more of the muscles innervated by the oculo-motor may be paralysed in nuclear lesions, but paralysis of all the muscles, unless forming part of a crossed paralysis—Weber's syndrome (p. 39)—indicates a lesion of the trunk of the nerve rather than a lesion of the nucleus.

The *nerves* themselves may be affected in purulent effusions into the cisterna interpeduncularis (p. 111), or in tumours of the interpeduncular fossa or surrounding areas. They may be subjected to pressure by tumours of the hypophysis (pituitary body) or by aneurisms of the internal carotid artery, as they pass forwards in the lateral wall of the cavernous sinus; or by tumours or hæmorrhages, as they lie in the orbit.

Results of Paralysis.—Paralysis of the *sixth nerve* only affects the lateral rectus muscle. The loss of movement results in the occurrence of a convergent strabismus when the patient looks towards the paralysed side. To overcome this disability, the patient tends to keep his head rotated to the side of the lesion, thus obviating the necessity for lateral rotation of the affected eye.

When the *fourth nerve* is involved by itself, the superior oblique is the only muscle which is paralysed. Under these circumstances, the eye deviates to the medial side when downward rotation is attempted, since the medial pull of the inferior rectus is no longer counter-balanced by the lateral pull of the superior oblique. The other movements of the eye are not affected, and disability is only noticed by the patient when he has to look downwards, *e.g.*, in going downstairs; he then suffers from diplo-opia.

In complete paralysis of the *third nerve* the eye only retains those movements which are due to the superior oblique and

the lateral rectus. When at rest, the paralysed eye looks downwards and laterally, and the patient, therefore, tends to walk with the head rotated to the opposite side so as to enable him to look directly forwards. In addition to the disability produced by the paralysis of the ocular muscles, *ptosis* results owing to paralysis of the levator palpebræ superioris. In an endeavour to counteract this condition, the patient extends the head on the trunk and actively contracts the frontalis muscle.

Owing to the paralysis of the sphincter pupillæ, the pupil is widely dilated by the unopposed dilator muscle (p. 67). The ciliary muscle is also affected and, therefore, the accommodation reflex is lost in addition to the light reflex.

The **Fifth** or **Trigeminal Nerve** contains both motor and sensory fibres, and it therefore possesses two nuclei. The Motor Nucleus is an elongated mass of grey matter, which lies in the upper half of the pons ; further, some cells which lie in the grey matter around the cerebral aqueduct (of Sylvius) in the mid-brain send their fibres down to join the motor root of the trigeminal. The nucleus receives fibres from the cortex of both cerebral hemispheres, and, therefore, *supra-nuclear lesions* do not cause complete paralysis of the muscles supplied on the opposite side of the body. *Nuclear lesions* are accompanied by complete paralysis of the muscles of mastication (p. 70) on the same side as the lesion ; they sometimes occur late in the course of bulbar paralysis (p. 108).

The Sensory Nucleus is placed in the lower half of the pons, and extends downwards through the whole length of the medulla oblongata into the spinal medulla, in which it reaches the level of the second cervical segment. In the pons, it lies postero-lateral to the nucleus of the facial nerve and lateral to the ascending sensory fibres (spino-thalamic tract) from the spinal medulla (Fig. 34). A *nuclear lesion*, therefore, not only causes anæsthesia in the area of distribution of the trigeminal, but it may also cause partial or complete anæsthesia of the limbs and trunk on the opposite side, owing to involvement

of the spino-thalamic tract. The condition is termed *alternate hemi-anæsthesia*, and it may or may not be accompanied by homo-lateral facial paralysis (p. 86).

The small *motor* and the large *sensory roots* emerge side by side from the lateral part of the pons near its upper border, and run laterally through the subarachnoid space before they pierce the dura mater at the apex of the petrous part of the temporal bone (Fig. 35). The acoustic (auditory) nerve, as

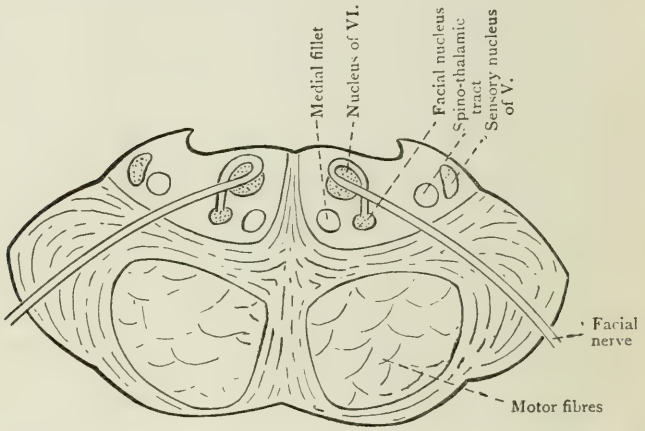


FIG. 34.—Transverse Section through the Pons (Diagrammatic).

it passes from the internal acoustic meatus to the pons, lies a little below the trigeminal. Paralysis of the fifth, with signs of cerebellar disease, and with or without symptoms of deafness, is diagnostic of tumour in the neighbourhood of the cerebello-pontine angle (p. 22).

The SEMILUNAR (GASSERIAN) GANGLION, which corresponds to the ganglion on the posterior root of a spinal nerve, is placed on the sensory root of the trigeminal as it lies on the anterior part of the petrous temporal. It lies immediately postero-lateral to the cavernous sinus and receives

branches from the cervical sympathetic, which enter the skull in company with the internal carotid artery (p. 186). These branches are destined to supply the dilator muscle of the iris.

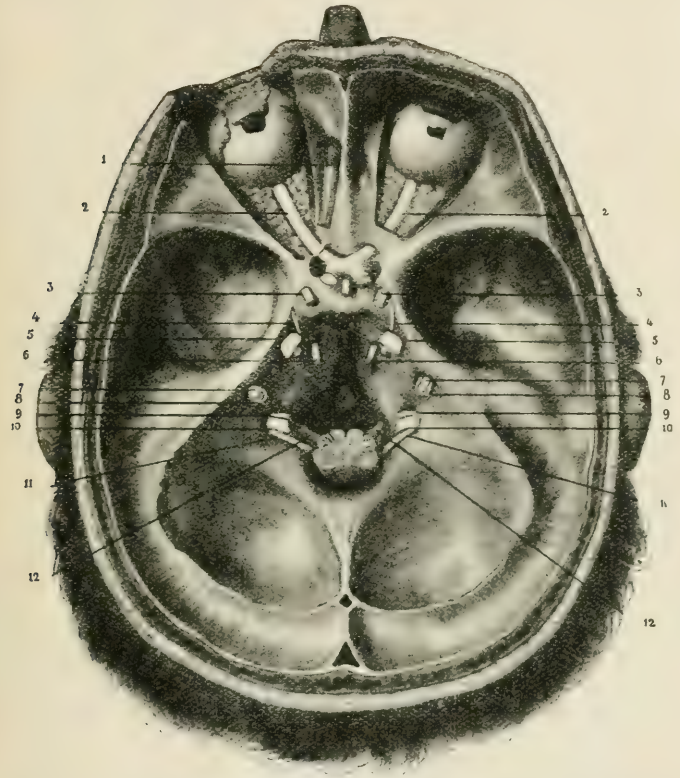


FIG. 35.—Interior of the Skull after the removal of the Brain, showing the points of exit of the twelve cerebral nerves.

The small motor root takes no part in the formation of the semilunar ganglion. Since it lies between the ganglion and the bone, it can be left behind uninjured when the ganglion is

removed. The ophthalmic, maxillary and mandibular (inferior maxillary) nerves arise from the anterior border of the semi-

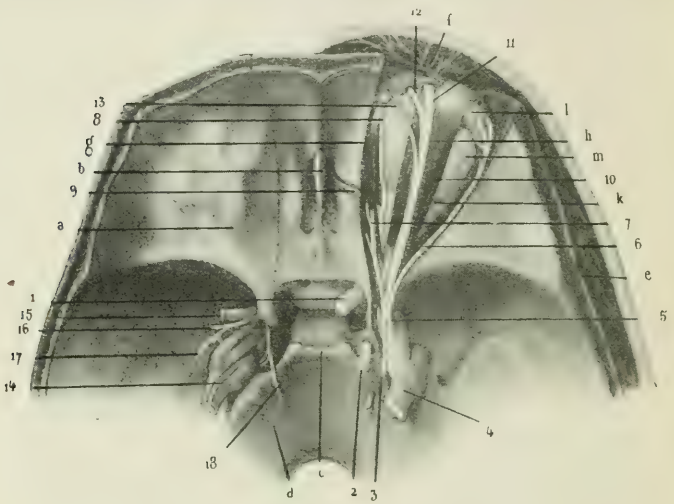


FIG. 36.—The Branches of the Ophthalmic Nerve.

a. Roof of orbit.
b. Crista galli.
c. Dorsum sellæ.
d. Petrous temporal.
e. Cut edge of skull.
f. Orbicularis oculi muscle.
g. Superior oblique muscle.
h. Levator palpebræ superioris.
k. Superior rectus muscle.
l. Lacrimal gland.
m. Eye-ball.
1. Optic nerve.
2. Oculo-motor nerve.
3. Trochlear nerve.
4. Trigeminal nerve.
5. Ophthalmic nerve.
6. Lacrimal nerve.
7. Trochlear nerve.
8. Infra-trochlear nerve.
9. Anterior ethmoidal nerve.
10. Frontal nerve.
11. Supra-orbital nerve (lateral branch).
12. Supra-orbital nerve (medial branch).
13. Supra-trochlear nerve.
14. Semilunar (Gasserian) ganglion.
15. Oculo-motor nerve.
16. Trochlear nerve.
17. Branch to tentorium cerebelli.
18. Abducent nerve.

lunar ganglion, and the last-named is joined by the whole of the small motor root.

1. The OPHTHALMIC NERVE, which is purely sensory, arises from the semilunar ganglion, and at once enters the lateral wall

of the cavernous sinus, where it is related to the third, fourth and sixth cerebral nerves, the internal carotid artery, and the hypophysis (pituitary body) (Fig. 31). At the anterior extremity of the sinus, it enters the orbit through the superior orbital (sphenoidal) fissure and breaks up into its terminal branches.

(*a*) The **Frontal Nerve** passes forwards in contact with the roof of the orbit and divides into the supra-orbital and the supra-trochlear nerves. The *supra-orbital* passes forwards and leaves the orbit through the supra-orbital notch, which may be felt on the upper border of the base of the orbit (orbital aperture) at a distance of two fingers'-breadth from the median plane. It then turns upwards and supplies a wide area of the skin of the forehead and scalp, extending as far back as the vertex (Fig. 37). In addition, the supra-orbital nerve supplies the skin and the underlying conjunctiva of rather more than the middle third of the upper eyelid. The sympathetic fibres which supply the ciliary bundle (p. 210) are probably carried by the supra-orbital nerve.

The *supra-trochlear* is a much smaller nerve, which supplies the skin and conjunctiva of the medial part of the upper eyelid and gives a few twigs to the skin of the forehead just above the root of the nose (Fig. 37).

(*b*) The **Lacrimal Nerve** passes forwards along the upper border of the lateral rectus muscle and receives a communicating branch from the zygomatic (orbital) nerve, which conveys the secreto-motor fibres (p. 69) for the lacrimal gland. After supplying the gland (p. 208), the nerve is distributed to the skin and conjunctiva of the lateral part of the upper eyelid (Fig. 37).

(*c*) The **Naso-ciliary (Nasal) Nerve** runs forwards across the optic nerve to the medial wall of the orbit. It gives off the *long root* to the ciliary ganglion and the *long ciliary nerves*, which pass forwards to the coats of the eyeball. In addition, it supplies the skin in the region of the medial canthus by means of the *infra-trochlear nerve*. The terminal branch of

the naso-ciliary nerve eventually reaches the nasal fossa and supplies branches to the mucous membrane of the septum and lateral wall. Finally, it emerges on the face and is distributed

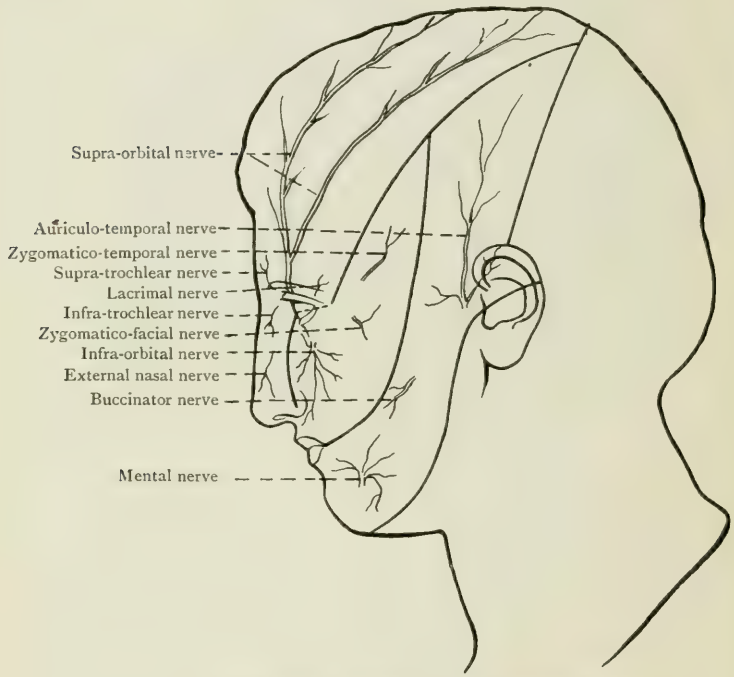


FIG. 37.—The Cutaneous Branches of the Trigeminal Nerve.

to the skin of the anterior part of the side of the nose (Fig. 37).

The **Ciliary Ganglion** lies in the orbital fat between the optic nerve and the lateral rectus muscle. It receives a short motor root from the oculo-motor, destined for the sphincter iridis and the ciliary muscle (p. 213), and a long root from the naso-ciliary nerve. The long root conveys some of the sym-

pathetic fibres which join the semilunar (Gasserian) ganglion, and they are destined for the dilatator iridis. The ciliary ganglion contains some nerve-cells which form a peripheral controlling centre for the light reflex. Degenerative changes have been found in the ganglion in cases showing a typical

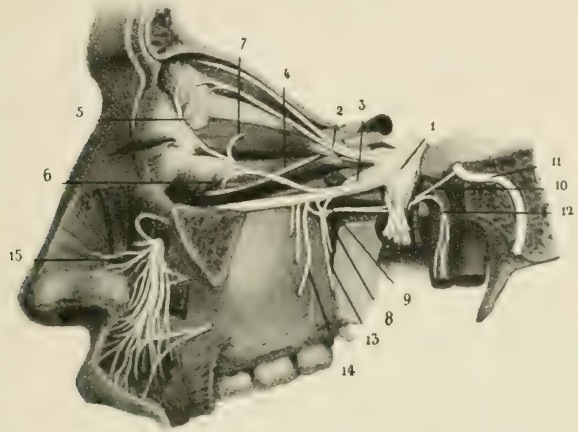


FIG. 38.—The Branches of the Maxillary Nerve.

1. Semilunar (Gasserian) ganglion.
2. Ophthalmic nerve.
3. Maxillary nerve.
4. Zygomatic nerve.
5. Branch communicating with lacrimal nerve.
6. Zygomatico-facial nerve.
7. Zygomatico-temporal nerve.
8. Spheno-palatine ganglion (of Meckel).
9. Nerve of pterygoid canal (Vidian).
10. Greater superficial petrosal nerve.
11. Facial nerve.
12. Deep petrosal nerve.
13. Palatine nerves.
14. Posterior superior alveolar (dental) nerve.
15. Infra-orbital nerve.

"Argyll-Robertson pupil" (p. 54). The short ciliary nerves arise from the ganglion and proceed forwards to the eyeball.

The various pathological conditions affecting the ophthalmic nerve are indicated on page 77.

2. The MAXILLARY NERVE is, like the ophthalmic, a purely sensory nerve. From the semilunar (Gasserian) ganglion it runs forwards on the floor of the middle cranial fossa,

lateral to the cavernous sinus, and passes through the foramen rotundum in the great wing of the sphenoid (Fig. 35). It then runs obliquely across the uppermost part of the pterygo-palatine (spheno-maxillary) fossa and enters the orbit through the inferior orbital (spheno-maxillary) fissure (Fig. 38).

In this part of its course the maxillary nerve can be reached with a hypodermic needle for the purpose of injecting absolute alcohol, or some other destructive agents, into and around it. The needle is entered immediately below the zygomatic arch at a point 4 cms. in front of the anterior wall of the external acoustic meatus (Symington). The nerve lies at a depth of 5 cms. from the surface, but it is probable that, before it reaches this depth, the needle will impinge either on the posterior part of the maxilla or on the lateral pterygoid lamina (Fig. 38). It will require to be withdrawn partially and re-inserted until it passes through the pterygo-maxillary fissure and enters the pterygo-palatine (spheno-maxillary) fossa. The contents of the syringe can then be injected around the maxillary nerve.

As the maxillary nerve lies in the pterygo-palatine fossa, it is connected to the spheno-palatine (Meckel's) ganglion by two roots (Fig. 38).

The **Spheno-Palatine Ganglion** receives additional afferent fibres from the nervus canalis pterygoidei (Vidian nerve), which is formed by the union of the greater superficial petrosal nerve from the facial with the deep petrosal nerve from the cervical sympathetic. Branches arise from the ganglion and are distributed to the mucous membrane (1) of the *lateral walls and septum of the nose*, (2) of the *hard palate and gums*, (3) of the *soft palate* and the *palatine* (*faucial*) *tonsil*, and (4) of the *roof of the nasal part of the pharynx*.

It is possible that the spheno-palatine ganglion takes part in the innervation of the muscles of the soft palate, but this view is not generally accepted (p. 96).

In the orbit, the maxillary nerve gives off the **zygomatic**

(orbital) nerve, which communicates with the lacrimal (p. 65) and emerges as two small branches to supply the skin of the face behind the eye (Fig. 37). The communicating branch conveys to the lacrimal the secreto-motor fibres for the lacrimal gland. These fibres probably emerge from the brain-stem with the facial nerve, and pass by the greater superficial petrosal to the spheno-palatine ganglion and the maxillary nerve.

In this situation, also, the maxillary gives off the **posterior superior alveolar (dental) nerve**, which is distributed to the molar teeth of the maxilla. It then enters the infra-orbital canal in the floor of the orbit (Fig. 38) and supplies the remaining maxillary teeth by means of the **middle** and the **anterior alveolar** branches. Finally, the maxillary nerve emerges from the infra-orbital foramen as the infra-orbital nerve and appears on the face.

The **infra-orbital nerve** breaks up into a large number of branches. They supply—(1) The skin and conjunctiva of the *lower eyelid*; (2) the skin on the postero-lateral aspect of the *nose*; (3) the skin and mucous membrane of the *upper lip*; (4) the skin and mucous membrane of the *cheek*. In addition, the infra-orbital nerve supplies sensory fibres to a large number of the facial muscles (p. 84).

3. The MANDIBULAR NERVE carries off the whole of the motor root of the trigeminal and, in addition, it contains a large number of sensory fibres. It arises from the lateral part of the semilunar ganglion, and leaves the interior of the skull by passing downwards through the foramen ovale (Fig. 35). This course brings it at once into the region of the pterygoid muscles, and, immediately below the skull, the nerve lies between the external pterygoid, on the lateral side, and the lateral wall of the naso-pharynx, on the medial side.

Corrosive fluids may be injected around the nerve in this part of its course, and they will affect it above the point where the important sensory branches arise. The mouth is held

open, preferably by a gag, so as to tilt the coronoid process forwards, and the needle is entered below the posterior part of the zygomatic arch and immediately in front of the temporo-mandibular joint (Fig. 39). It is passed medially and slightly backwards for a distance of 4 cms. from the surface, and the contents of the syringe may then be injected (Symington). The masseter, temporal and both pterygoid muscles are pierced in turn, and their bulk accounts for the depth to which the needle must be thrust. As in the case of the maxillary nerve, it is advisable to perform the operation without an anæsthetic, as the severe pain caused by the entrance of the point of the needle into the nerve is the surest guide to the site of injection. Care must be taken not to pass the needle in too far, as it may pierce the lateral wall of the naso-pharynx or the terminal part of the auditory (Eustachian) tube (p. 329).

The **Otic Ganglion** is connected with the mandibular nerve immediately below the foramen ovale. It receives fibres not only from the trigeminal but also, through the lesser superficial petrosal nerve (p. 92), from the facial and the glosso-pharyngeal nerves. The *efferent fibres* are partly secretory and partly motor. The *secretory fibres* join the auriculo-temporal nerve, and are conveyed by it to the parotid gland; the *motor fibres* supply the tensor tympani (p. 204) and the tensor veli palatini (tensor palati). It is not yet certain whether the motor fibres originate in the motor nucleus of the fifth or the seventh.

The mandibular nerve is responsible for the innervation of the Muscles of Mastication. They include the temporal, the masseter, the internal pterygoid, the external pterygoid, the mylo-hyoid and the anterior belly of the digastric.

The **Temporal** and the **Masseter** muscles *elevate* the mandible and are rendered tense when the teeth are firmly clenched. The contractions of the temporal muscle can be appreciated best near its upper border, about 2 inches or

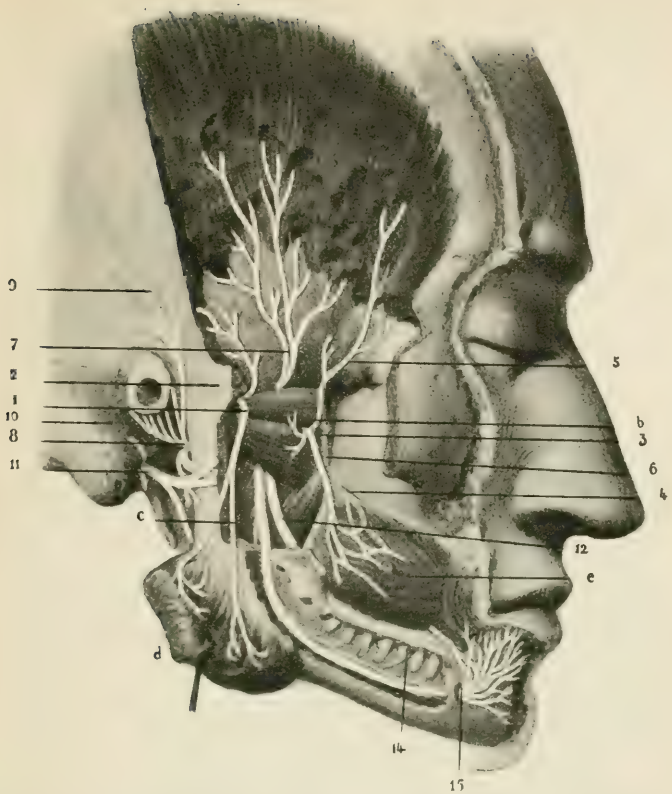


FIG. 39.—The Branches of the Mandibular Nerve. The zygomatic arch and a portion of the ramus of the mandible have been removed. In addition, the lower part of the temporal muscle has been resected and the masseter has been turned downwards.

b. External pterygoid muscle.
c. Internal pterygoid muscle.
d. Masseter muscle.
e. Buccinator muscle.
1. Masseteric nerve.
2. Temporo-mandibular joint.
3. Buccinator nerve.
4. Maxilla.
5. Branch to temporal muscle.
6. Lateral pterygoid lamina.
7. Deep temporal nerve.
8. Auriculo-temporal nerve.
9. Temporal fascia.
10. Mastoid process.
11. Facial nerve.
12. Lingual nerve.
14. Roots of teeth.
15. Mental branch of inferior alveolar (dental) nerve.

more above the zygomatic arch. At a lower level, the temporal fascia is so strong and dense that the contractions of the muscle cannot be felt. The contractions of the masseter can be felt in the posterior part of the side of the face, below the zygomatic arch.

The **Pterygoid Muscles** arise in the region of the pterygoid process of the sphenoid, and pass backwards and laterally to be inserted into the mandible. They therefore *protrude* the mandible and *move it from side to side*. They are deeply situated under cover of the mandibular ramus, and their contractions cannot be examined satisfactorily. When the pterygoid muscles of one side act in unison, that half of the mandible is drawn towards the median plane, and the opposite half is consequently thrust in a lateral direction. No other muscles assist the pterygoids in producing side to side movements.

The **Mylo-hyoid** and the **Anterior Belly of the Digastric** act as *depressors* of the mandible. The former extends from the mylo-hyoid line on the inner surface of the body of the mandible to the body of the hyoid bone. The anterior fibres of the two mylo hyoids are inserted into a median raphe, which extends from the symphysis menti to the middle of the hyoid bone, and together they form a muscular floor for the mouth. In addition to their action as depressors of the mandible, the mylo-hyoids act as elevators of the hyoid bone, when the mandible is fixed, *e.g.* in swallowing (p. 229), and they steady the hyoid during the movements of the tongue.

In the median plane, between the chin and the hyoid bone, the mylo-hyoid is covered only by the skin and fasciæ and its contractions can be palpated in this situation. They are felt most readily when the tongue is pressed against the hard palate. Unfortunately, the genio-hyoid (p. 106) is rendered tense by the same action and, in consequence, paralysis of the mylo-hyoid is very difficult to determine.

The *anterior belly of the digastric* is probably more efficient

as an elevator of the hyoid bone than as a depressor of the mandible. The *posterior belly* (facial nerve, p. 81) arises on the medial side of the base of the mastoid process and passes forwards and downwards, deep to the angle of the mandible, to the greater cornu of the hyoid bone. It terminates in the common tendon of the muscle, which is attached to the greater cornu by a slip of the deep cervical fascia. The anterior belly passes forwards and medially from the common tendon to be attached to the base of the mandible near the median plane. It is placed superficial to the mylo-hyoid, but is partially overlapped by the submaxillary salivary gland.

Paralysis of the motor part of the trigeminal is usually accompanied by some involvement of the sensory fibres. Owing to bilateral representation in the cerebral cortex (p. 34), the muscles of mastication are rarely affected in lesions of the internal capsule or the corona radiata.

Nuclear lesions have already been referred to (p. 61).

The motor root of the fifth, as it lies on the apex of the petrous part of the temporal bone, may be affected in syphilitic basal meningitis, and, in these cases, the whole of the sensory distribution of the trigeminal will be involved, probably together with the third and fourth cerebral nerves.

The motor root may be affected in extra-cranial tumours which compress the mandibular nerve.

In complete motor paralysis of the trigeminal the principal disability is caused by the lack of opposition to the pterygoid muscles of the sound side. The unparalysed elevators and depressors are sufficiently powerful to carry out their respective movements, but the tonus of the unopposed pterygoids causes the jaw to be thrust over to the paralysed side, and so the teeth do not oppose one another in a satisfactory manner during mastication.

Some authorities state that the free border of the soft palate lies at a lower level on the paralysed side, but others have failed to observe any affection either of the soft palate

or of the sense of hearing (tensor veli palatini and tensor tympani, p. 204).

Four large sensory branches arise from the mandibular nerve immediately below the foramen ovale.

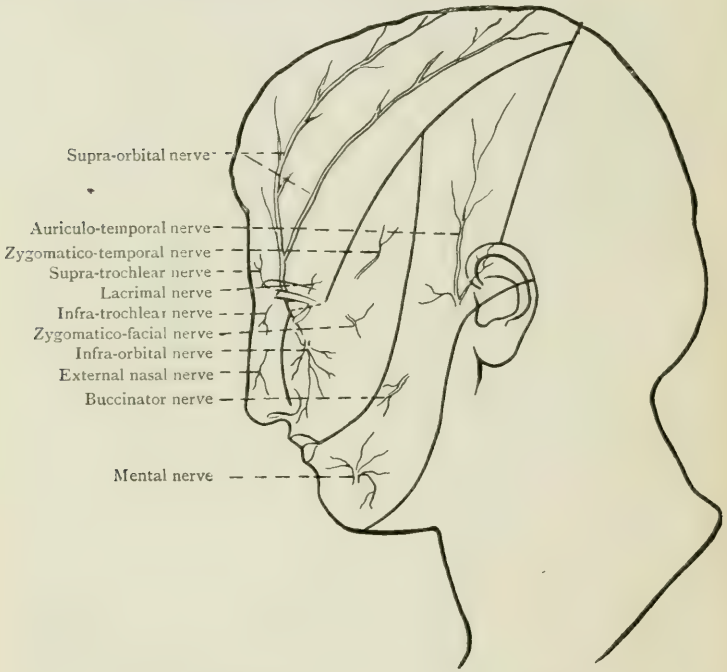


FIG. 40.—The Cutaneous Branches of the Trigeminal Nerve.

1. The **Auriculo-temporal Nerve** receives a communicating branch from the otic ganglion (p. 70) and passes backwards under cover of the neck of the mandible. It then enters the parotid gland and, after supplying it with secretory fibres, ascends over the zygomatic arch immediately in front of the

external ear. The full distribution of the nerve includes a strip of skin on the side of the head (Fig. 40), the skin of the upper and anterior part of the external ear, and the skin which lines the external acoustic meatus and the lateral aspect of the tympanic membrane.

2. The **Buccinator (Long Buccal) Nerve** supplies the skin of the cheek behind the area innervated by the infra-orbital nerve (Fig. 40). Many of its branches pierce the substance of the cheek and supply the mucous membrane. When the buccinator nerve is paralysed, portions of food tend to remain lodged in the grooves between the cheek and the gums. This is due to anæsthesia of the mucous membrane and not to paralysis of the buccinator muscle, which is supplied by the facial nerve (p. 82).

3. The **Inferior Alveolar (Dental) Nerve** enters the mandibular canal and supplies all the teeth of the lower jaw. Its terminal branch, termed the *mental nerve*, emerges on the outer surface of the mandible through the mental foramen and supplies the skin of the lower lip, the chin and adjoining areas and the mucous membrane of the lower lip (Fig. 40).

4. The **Lingual Nerve** descends under cover of the ramus of the mandible and passes forwards deep to the body of the bone to enter the submaxillary region and reach the tongue (Fig. 49). It supplies the mucous membrane of the floor of the mouth and the anterior two-thirds of the tongue with ordinary sensation. When a spatula is introduced into the mouth, no unpleasant sensations are aroused as long as the instrument is in contact with the area supplied by the lingual nerve, but if it touches the posterior third—or the posterior part of the middle third, for the nerves supplying adjoining areas overlap one another in their distribution—the glosso-pharyngeal nerve is stimulated and the pharyngeal reflex is set up.

In the first part of its course, the lingual nerve is joined by the *chorda tympani* (p. 84), through which it supplies taste

fibres to the anterior two-thirds of the tongue. The course of the taste fibres is discussed on page 84.

The **Submaxillary Ganglion** is connected with the lingual nerve, as it lies on the side of the tongue. The afferent

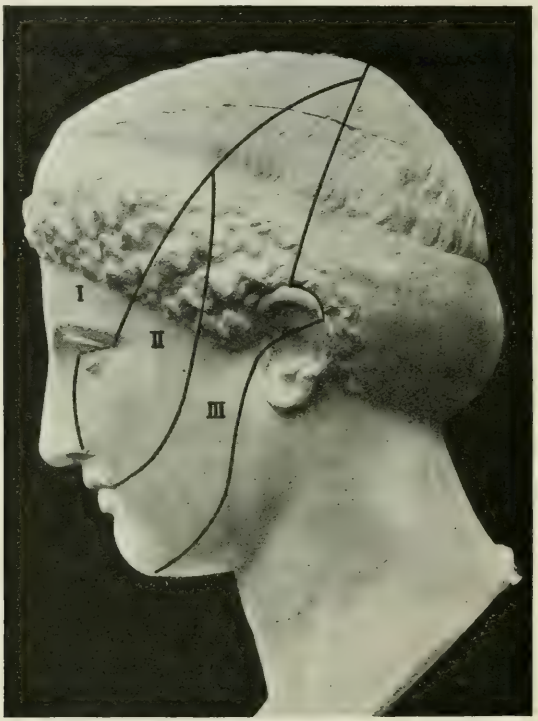


FIG. 41.—The Areas of Skin supplied by the three divisions of the Trigeminal Nerve.

fibres from the nerve to the ganglion are derived from the chorda tympani (p. 84). They are the secretory nerves for the submaxillary and sublingual salivary glands, to which they are distributed.

In Fig. 41 the areas of distribution of the three great divisions of the trigeminal have been indicated schematically. It will be observed that the trigeminal is responsible for the supply of the skin of the whole of the face with the exception of a small area over the angle of the mandible, which is supplied by the great auricular nerve (C. 2 and 3). In addition, it supplies the skin of the anterior part of the head, the upper part of the external ear and the skin lining the external acoustic meatus.

The sensory branches of the fifth also supply a wide area of mucous membrane, including the conjunctival sacs, the nose, cheeks, lips, gums, palate, floor of the mouth and anterior two-thirds of the tongue.

Paralysis of the Sensory Part of the Trigeminal Nerve

Lesions of the sensory nucleus are usually associated with the condition of alternate hemi-anæsthesia (p. 62).

Complete unilateral anæsthesia in the region supplied by the fifth nerve, unaccompanied by anæsthesia in other regions, indicates a lesion of the large sensory root or the semilunar (Gasserian) ganglion, usually caused by an intracranial tumour in the cerebello-pontine angle. The cutaneous anæsthesia reaches exactly to the median plane, as the two trigeminal nerves do not overlap one another. As a result, when the patient drinks from a vessel, it feels to him as if it were broken, since the part in contact with the anæsthetic halves of the lips cannot be appreciated.

Trigeminal paralysis also produces marked effects on the areas of mucous membrane which are rendered anæsthetic. The mucous membranes of the nose, cheeks and tongue become dry, and atrophic changes may occur. Ulceration of the cornea is not uncommon.

Trigeminal Neuralgia.—Conditions which give rise to pain in the areas supplied by the trigeminal may be immediately or only remotely connected with the nerve itself.

The lesion in *tic douloureux* is not definitely known, but it presumably affects either the semilunar (Gasserian) ganglion or the sensory root of the nerve. In this case the pain starts in one particular branch and, later, spreads to affect other branches of the same division. It is important to observe that the pain is restricted to the areas of peripheral distribution (Fig. 41). After a time, hyperæsthetic areas develop in the skin of the face or head, and their appearance is due to the establishment of a "focus of irritation" (p. 195) in the sensory nucleus of V.

Pain of a similar nature may be caused by an intracranial tumour in its early stages.

Referred pain (p. 190) occurs in the trigeminal area with great frequency. Head has pointed out that two distinct varieties of referred pain occur in this area. In one the pain is radiating or neuralgic in type and affects the area of distribution of a definite branch or branches of the trigeminal. Pyorrhœa alveolaris gives rise to such a condition and may be accompanied by the development of localised areas of hyperæsthesia, which are restricted to the same regions.

In the other variety, the pain does not radiate and is constantly referred to a definite area, which does not correspond to the peripheral distribution of any one branch of the fifth. Hyperæsthetic areas may develop, and they are localised to the same "segmental" regions. This variety of referred pain is met with in iritis, glaucoma and inflammation of the tooth pulp. The lower molars are intimately related to the skin over the posterior part of the ramus of the mandible and to the skin lining the external acoustic meatus. In irritation of the pulp of a lower molar, there may be no local pain and yet the ear pain may be very acute. These cases may readily lead to wrong diagnosis.[1]

When a "focus of irritation" (p. 195) is established in the

[1] For a full description of the "segmental" areas and their relation to the teeth, the reader is referred to Head's article in Allbutt and Rolleston's *System of Medicine*.

sensory nucleus of the trigeminal, it may spread to affect the neighbouring grey matter. As a result, pain may be experienced, or hyperæsthetic areas may develop, on the side of the neck in areas supplied by C. 2 and 3 (Fig. 69).

It must also be remembered that, when a "focus of irritation" is established in a sensory nucleus which is related to the sensory nucleus of the trigeminal, the latter may also be stimulated. This explanation accounts for the occurrence

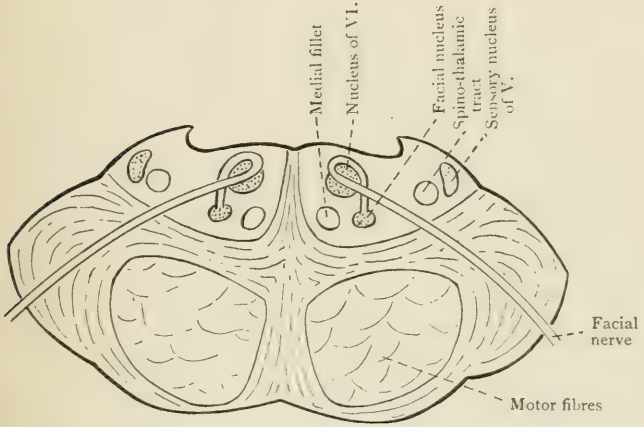


FIG. 42.—Transverse Section through the Pons (Diagrammatic).

of pain in the head or face in lesions of the lungs, heart or stomach. The pathological afferent impulses set up a "focus of irritation" in the sensory nucleus of the vagus, and from there they spread to affect the sensory nucleus of the fifth (Fig. 47).

The **Facial** or **Seventh Cerebral Nerve** consists of a large motor root and a small sensory root which is termed the *nervus intermedius* (*of Wrisberg*) The motor root arises in a nucleus, which is situated in the substance of the pons,

dorsal to the bundles of the pyramidal tract and medial to the sensory nucleus of the trigeminal (Fig. 42). After they leave the nucleus, the efferent fibres pass backwards and curl round the nucleus of the sixth nerve, at the same time forming an elevation in the floor of the fourth ventricle (p. 56). They then turn forwards and pass through the whole substance of the pons, finally emerging near its lower border (Fig. 8).

The motor part of the facial, the nervus intermedius, and the eighth nerve pass laterally together through the subarachnoid space and enter the petrous part of the temporal bone through the internal acoustic meatus.

At the bottom of the internal acoustic meatus, the facial and the nervus intermedius enter a small canal, in which they pass laterally to the medial wall of the tympanic cavity. At this point the canal bends sharply backwards, and a small swelling, termed the *geniculate ganglion*, is situated on the facial nerve. It is from this ganglion that the nervus intermedius arises. The course taken by the sensory fibres of the seventh is described on page 84.

As the facial canal passes backwards along the medial wall of the tympanum, the facial nerve is separated from the middle ear only by a thin plate of bone, which may readily become necrosed in otitis media. Opposite the aditus to the tympanic (mastoid) antrum (p. 206), the nerve makes a second bend, this time in a downward direction, and reaches the stylo-mastoid foramen on the inferior surface of the skull. As it descends in the last stage of its passage through the temporal bone, the facial nerve is joined by the **chorda tympani** and it gives off the nerve of supply to the stapedius muscle.

The *stapedius muscle* arises within the posterior wall of the tympanic cavity and passes forwards to be inserted into the neck of the stapes (p. 205). It would appear to act as an antagonist of the tensor tympani, for the condition of *hyperacousis* results when the stapedius is paralysed. In this

condition, certain sounds become greatly exaggerated and the patient may even complain that they cause definite pain. The stapedius is not paralysed in supra-nuclear lesions of the facial, and it is, therefore, believed that it possesses bilateral representation in the cerebral cortex.

The course of the chorda tympani is described on page 84.

It is sometimes desirable to apply a counter-irritant over

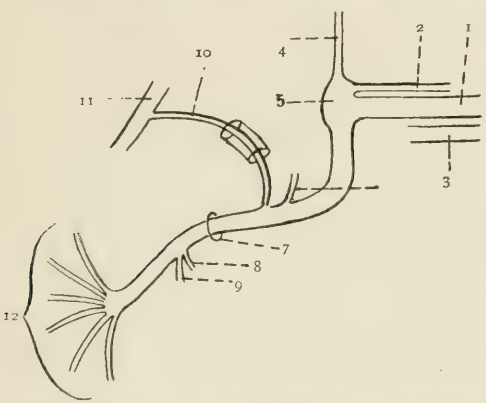


FIG. 43.—Schematic representation of the Branches of the Facial Nerve.

1. Facial nerve.
2. Nervus intermedius (of Wrisberg).
3. Acoustic nerve.
4. Greater superficial petrosal nerve.
5. Geniculate ganglion.
6. Nerve to stapedius.
7. Stylo-mastoid foramen.
8. Posterior auricular nerve.
9. Nerve to stylo-hyoid and posterior belly of digastric.
10. Chorda tympani.
11. Lingual nerve
12. Terminal branches of facial nerve.

the facial nerve at the point where it emerges from the stylo-mastoid foramen. This point corresponds on the surface to the upper part of the depression between the mastoid process and the external ear.

After leaving the skull, the facial nerve gives off certain muscular branches, before it enters the parotid gland. These branches are distributed to the *occipitalis*, the *posterior* and *superior auricular muscles*, and the *posterior belly of the digastric*

and the *stylo-hyoid*. No description of the actions, etc., of these muscles is necessary, as their investigation is rarely called for in cases of facial paralysis.

In the parotid gland the facial nerve passes forwards across the lateral aspect of the neck of the mandible, and, in this situation, it is exposed to injury, *e.g.* by the application of forceps during delivery. As the fascial sheath of the gland is so strong that even a slight enlargement of the parotid may be sufficient to exert pressure on the nerve, facial paralysis may be a complication of acute parotitis.

The terminal branches of the facial nerve arise within the parotid gland and they supply *all the muscles of facial expression*, including the *buccinator*, the *platysma* and the *frontalis*.

Peripheral Lesions of the Facial Nerve.—In complete facial paralysis, due to a lesion *outside the skull*, all the muscles of expression are completely paralysed. As a result, the affected side of the face is immobile and the natural skin creases disappear.

The **Orbicularis Oculi (Palpebrarum)** lies partly in the eyelids and partly around the margins of the base (external aperture) of the orbit. It acts as a sphincter of the eyelids and its tonus serves to keep the puncta lacrimalia closely applied to the surface of the eye (p. 210). When this muscle is paralysed, the eye remains open and attempts to close it result only in upward rotation of the eyeball. The conjunctival reflex is therefore abolished, but automatic winking does not cease and the eye may become closed during sleep. These two latter movements are due to relaxation of the levator palpebræ superioris. In addition, paralysis of the orbicularis oculi is accompanied by the condition of epiphora (p. 210).

The **Buccinator** forms the muscular stratum of the cheek. Its fibres arise from the inner alveolar borders of the mandible and maxilla, opposite the molar teeth, and also from a ligamentous band, termed the pterygo-mandibular

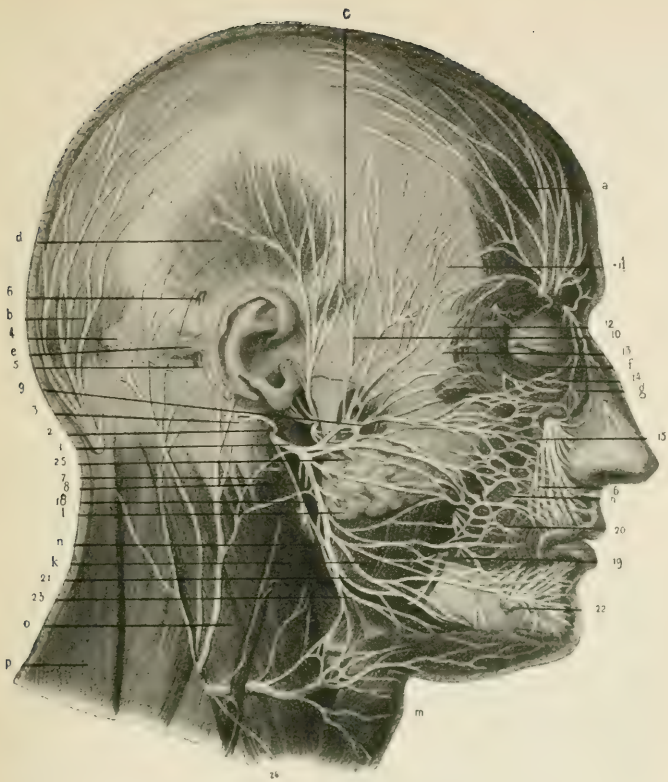


FIG. 44.— The Facial **Nerve** and its Ramifications.

a. Frontalis muscle.
b. Occipitalis muscle.
c, *d*, *e*. Auricular muscles.
f. Orbicularis oculi muscle.
g. Quadratus labii superior muscle.
h. Buccinator muscle.
k. Masseter muscle.
l. Parotid gland.
m. Laryngeal prominence.
n. Digastric muscle, posterior belly.
o. Sterno-mastoid muscle.
p. Trapezius muscle.
1. Facial nerve.
2. Posterior auricular nerve.
3. Mastoid process.
4. Nerve to occipitalis muscle.
5. 6. Nerves to auricular muscles.
7. Communication between facial and great auricular nerves.
8. Nerve to stylo-hyoid.
9. Temporo-facial division.
10–14. Temporal branches.
15. Zygomatic branches.
16. Infra-orbital nerve.
18. Cervico-facial division.
19, 20. Buccal branches.
21. Mandibular branches.
22. Mental nerve.
23. Cervical branch.
24. Nervus cutaneus colli.
25. Parotid branches of auriculo-temporal nerve.

raphe. They pass horizontally forwards and blend with the *orbicularis oris* at the angle of the mouth. When the buccinator contracts, it draws the angle of the mouth backwards, but, if the angle of the mouth is fixed, *e.g.* by the contraction of the orbicularis oris, it compresses the cheek against the gum. This latter action can readily be tested if the finger is placed in the groove between the gum and the cheek. In paralysis of the buccinator, as also in trigeminal paralysis (p. 75), portions of food tend to remain lodged in this groove and, by decomposition, they impart a foul odour to the breath. Further, the unopposed buccinator of the sound side draws the mouth over to that side, and this deformity is very characteristic of all varieties of facial palsy.

The **Orbicularis Oris** forms a sphincter muscle for the mouth. It is called into action in closing the mouth and it purses the lips in whistling and sucking. Other muscles, which need not be detailed, aid the orbicularis in movements of the lips. Paralysis of these muscles not only results in the dribbling of fluids, saliva, etc., from the mouth, but also renders the pronunciation of labials and labio-dentals (*b*, *c*, *f*, *m*, *p*, *o* and *r*) slurred and indistinct.

Before the results of intra-cranial lesions of the facial nerve are described, it is necessary to refer to the path of the taste fibres and the functions of the chorda tympani.

The **Chorda Tympani** contains both afferent and efferent fibres. The nerve begins in the descending part of the facial canal and passes forwards into the tympanum. It crosses the deep surface of the tympanic membrane near its upper border (p. 202) and then runs through a small bony canal to gain the infra-temporal fossa (pterygo-maxillary region), where it joins the lingual nerve.

It contains the taste fibres from the anterior two-thirds of the tongue and the secretory fibres for the submaxillary and sublingual salivary glands. The *taste fibres* run first in the lingual and then in the chorda tympani, which conveys them to the facial. *In the latter they pass to the geniculate ganglion*,

but their subsequent course to the brain is still doubtful. According to Ramsay Hunt, they leave the geniculate ganglion in the nervus intermedius, enter the pons and terminate in the upper part of the nucleus of the *tractus solitarius* (p. 91). According to other authorities, they leave the geniculate

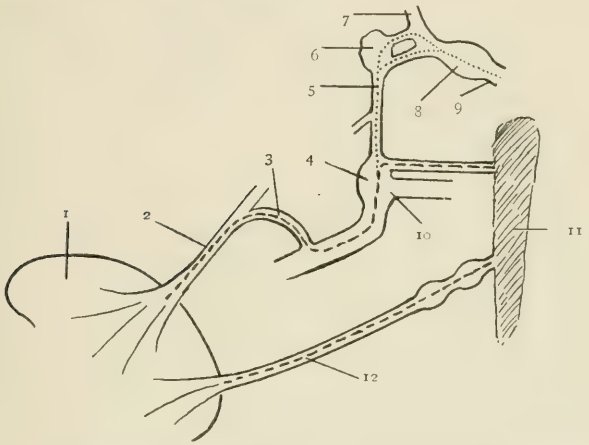


FIG. 45.—Schematic representation of the course of the Taste Fibres.

---- Course of taste fibres. ..... Alternative route.

1. Tongue.
2. Lingual nerve.
3. Chorda tympani.
4. Geniculate ganglion.
5. Nerve of pterygoid canal (Vidian nerve)
6. Spheno-palatine ganglion.
7. Maxillary nerve.
8. Semilunar (Gasserian) ganglion.
9. Trigeminal nerve.
10. Facial nerve.
11. Nucleus of tractus solitarius.
12. Glosso-pharyngeal nerve.

ganglion by the greater superficial petrosal nerve, by which they are conveyed to the spheno-palatine ganglion (p. 68); in this way they reach the maxillary nerve and enter the pons in the sensory root of the trigeminal.

The *secretory fibres* are stated to arise in the motor nucleus of the facial, and they run in the facial nerve until they reach the chorda tympani (Fig. 45), by which they are conveyed,

via the lingual nerve and the submaxillary ganglion, to their distribution.

It is now possible to study the effects of intra-cranial lesions of the fibres which constitute the facial nerve.

Supra-nuclear Lesions may be cortical or subcortical in origin. In these cases there is usually some additional paralysis either of the upper limb muscles or of the muscles supplied by the hypoglossal (p. 106). Owing to bilateral representation in the cerebral cortex, the muscles, though much weakened, are not completely paralysed. This applies more especially to the muscles of the upper part of the face. The orbicularis oculi, to outward appearances, is functioning normally, but when the patient endeavours to close the eye against resistance, the presence of weakness on the affected side is at once determined.

The mouth is drawn over to the sound side as in the case of peripheral lesions, but, in the expression of emotions, the two sides of the face become symmetrical, since it is in such movements that the muscles around the mouth are most commonly associated.

Since the lesion affects the upper neurones, the electrical reactions of the muscles paralysed are unaffected.

The sensation of taste is not interfered with, and there is no disturbance of the salivary or lacrimal secretions. The stapedius, being bilaterally represented in the cortex, is not paralysed.

Nuclear Lesions rarely occur alone and are almost always associated with bulbar paralysis (p. 108). An intra-pontine hæmorrhage may affect either the nucleus or the intra-pontine part of the nerve. In this case, the sixth nucleus (or its emerging fibres) and the pyramidal tract are also involved (Fig. 42). In the resulting paralysis, the sixth and seventh nerves are paralysed on the side of the lesion, but the limbs are paralysed on the opposite side. This crossed paralysis is known as the " Millard-Gubler syndrome " and the position of the lesion can be definitely located to the pons. The con-

dition may be accompanied by some degree of alternate hemi-anæsthesia (p. 62).

Cases of nuclear lesions of the facial have been recorded in which the orbicularis oculi and the orbicularis oris have escaped paralysis, and they have led to the suggestion that these muscles are innervated from the nuclei of the third and twelfth nerves respectively. There is, however, no anatomical evidence in support of this view, which is founded entirely on clinical evidence.

In lesions of the facial nerve situated between the surface of the pons and the geniculate ganglion, the acoustic nerve, which is so closely related to the facial in this part of its course, is usually involved (Fig. 51). On this account the paralysis of the stapedius cannot be determined. According to Ramsay Hunt, the sense of taste is lost over the anterior two-thirds of the tongue on the affected side, since the lesion is almost certain to involve the nervus intermedius. All the facial muscles on the affected side are paralysed and, as the lesion affects the lower neurone, the electrical reactions become altered and the muscles atrophy.

Lesions affecting the facial nerve between the geniculate ganglion and the origin of the chorda tympani usually result from otitis media. The acoustic nerve is not affected and the condition of hyperacousis, due to paralysis of the stapedius muscle, may sometimes be determined. The sense of taste is lost over the anterior two-thirds of the tongue on the affected side. The condition of the facial muscles is exactly the same as in the lesion described in the preceding paragraph.

In extra-cranial lesions (p. 82), only muscular paralysis is present. The special senses are unaltered.

The **Acoustic** or **Eighth Cerebral Nerve** is made up of two parts, termed (*a*) the COCHLEAR and (*b*) the VESTIBULAR nerve. The two meet at the bottom of the internal acoustic meatus and run together, within a common sheath, to the surface of the pons, where they separate.

(*a*) The fibres of the COCHLEAR NERVE arise in the spiral

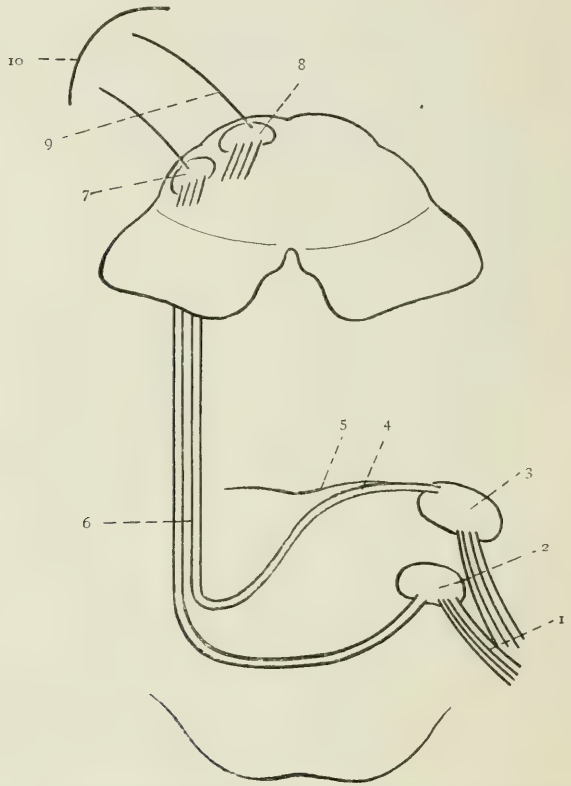


FIG. 46.—Diagram to show the path of the Fibres of the Cochlear Nerve.

1. Cochlear nerve.
2. Ventral cochlear nucleus.
3. Lateral cochlear nucleus.
4. Striæ medullares (acousticæ).
5. Floor of fourth ventricle.
6. Lateral fillet.
7. Medial geniculate body.
8. Inferior corpus quadrigeminum.
9. Acoustic radiation.
10. Cortex of superior temporal gyrus.

ganglion (of Corti) and they terminate in two nuclei, which lie in the lower part of the pons and the upper part of the

medulla oblongata. A new relay of fibres arises in these nuclei and, although some ascend through the same side of the brain-stem and do not undergo decussation, the majority cross the median plane. Many of the latter lie on the dorsal surface of the pons and form transverse ridges, termed the striæ acousticæ, which can be seen in the floor of the fourth ventricle (Fig. 32). Having crossed the median plane, the acoustic fibres turn upwards and form a tract, known as the *lateral fillet.* This tract ascends through the medulla oblongata and the pons to terminate in the lower acoustic centres —the *medial geniculate body* (p. 19) and the *inferior corpus quadrigeminum* (p. 18). From these centres new fibres arise which at once enter the posterior limb of the internal capsule. In this situation they are mingled with ascending sensory fibres from the opposite side of the body, but they lie in front of the visual fibres and behind the motor fibres for the lower limb. After leaving the internal capsule the acoustic fibres pass laterally to reach the higher centres, which are situated in the cortex of the superior temporal gyrus (p. 9).

Supra-nuclear Lesions of the acoustic tract never cause complete deafness unless they are bilateral, on account of the connexions of the cochlear nuclei with the cortex of both cerebral hemispheres.

Cortical Lesions may give rise to *word-deafness*, when they occur in the superior temporal gyrus of the left side in right-handed individuals. In this condition words can be heard as sounds but they cannot be understood.

Occasionally, in lesions affecting the posterior limb of the internal capsule, some degree of unilateral deafness may be associated with hemi-anæsthesia. Cases of hemi-anæsthesia accompanied by complete unilateral deafness are always hysterical in origin.

In Infra-nuclear Lesions the cochlear and vestibular nerves are often involved together (*vide infra*, p. 90). In some cases the cochlear nerve may be involved alone. It is then necessary

to determine whether the deafness is due to the condition of the nerve or to the condition of the conducting apparatus. If otoscopic examination is not sufficient, Weber's test may be employed. The base of a vibrating tuning-fork is applied to the vertex in the median plane. If the unilateral deafness is due to an affection of the nervous mechanism, the tuning-fork will be heard only, or much more distinctly, on the sound side; on the other hand, if the conducting apparatus is at fault, the tuning-fork will be heard better on the affected side.

(*b*) The VESTIBULAR NERVE carries afferent fibres from the vestibule and the semicircular ducts (canals). It runs with the cochlear nerve from the bottom of the internal acoustic meatus to the surface of the brain-stem, where they become separated by the restiform body. The fibres of the vestibular nerve terminate in several nuclei within the medulla oblongata and from these nuclei new fibres arise which connect the nerve with the cerebral cortex, the cerebellar cortex and the grey matter of the spinal medulla (spinal cord).

NOTE.—In the above descriptions of the connexions of the cochlear and the vestibular nerves, it has been deemed unnecessary to incorporate any more than a rough outline. For a more detailed account the reader must consult the standard text-books of Anatomy or Neurology.

Both the cochlear and the vestibular nerves are affected (1) in lesions of the acoustic nerve and (2) in inflammation or hæmorrhage into the membranous labyrinth (p. 208).

1. The acoustic nerve may be involved in cerebral tumours of the cerebello-pontine angle (p. 22), in purulent exudates in the cisterna pontis, or in syphilitic meningitis in the neighbourhood of the internal acoustic meatus. The symptoms directly referable to the acoustic nerve are the same as those described in the following paragraph.

2. Pathological conditions of the labyrinth give rise to a train of symptoms, which are grouped together under the name of *Menière's disease*. The lesion may be of the nature of a progressive inflammation or it may take the form of a hæmorrhage into the labyrinth. The symptoms are naturally

divided into two groups: (*a*) those referable to the cochlear nerve, and (*b*) those referable to the vestibular nerve.

(*a*) When the disease is slowly progressive in type, tinnitus is the symptom which is first noticed. Later, gradually increasing unilateral deafness becomes more apparent. In the case of sudden hæmorrhage into the labyrinth, deafness is sudden in onset and is, in the first instance, complete.

(*b*) Involvement of the vestibular nerve causes attacks of giddiness and vertigo. They may occur in the course of the

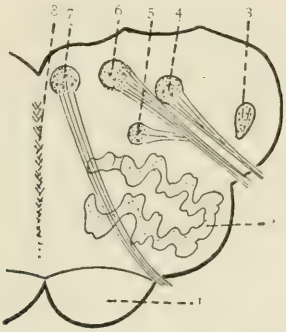


FIG. 47.—Section through Upper Part of Medulla Oblongata.

1. Pyramidal tract.
2. Olivary nucleus.
3. Sensory nucleus of V.
4. Nucleus of tractus solitarius.
5. Nucleus ambiguus.
6. Nucleus of vagus nerve.
7. Nucleus of hypoglossal nerve.
8. Sensory decussation.

disease without any premonitory symptoms, and the patient usually falls to the ground, although he does not necessarily lose consciousness.

The **Glosso-pharyngeal or Ninth Cerebral Nerve** contains both motor and sensory fibres. The motor fibres arise from the upper extremity of the *nucleus ambiguus* (p. 94) in the upper part of the medulla oblongata. The sensory fibres arise in the superior and the petrosal ganglia of the glosso-pharyngeal nerve and establish connexions centrally with the *tractus*

solitarius, an elongated column of grey matter (Fig. 47) which also receives some of the sensory fibres of the vagus.

The glosso-pharyngeal nerve leaves the medulla oblongata at the upper end of the groove between the olive and the restiform body (Fig. 8), and passes out of the skull through the jugular foramen in company with the vagus and accessory nerves. In its extracranial course the nerve is very deeply situated, and it inclines downwards and medially in the neck to reach the lateral wall of the pharynx.

Two ganglia, termed the *ganglion superius* and the *ganglion petrosum*, are found on the nerve as it lies in the jugular foramen.

The **tympanic branch** arises from the petrosal ganglion and, passing through a minute canal in the petrous temporal, enters the middle ear, where it breaks up into a small plexus. A branch emerges from this plexus and unites with a small branch from the geniculate ganglion of the facial to form the **lesser superficial petrosal nerve**, which ends in the otic ganglion (p. 70). In this way the glosso-pharyngeal nerve establishes communications with both the mandibular and the facial nerves.

It is said that the secretory fibres for the parotid gland leave the glosso-pharyngeal in the tympanic branch and travel in the lesser superficial petrosal nerve to the otic ganglion, from which they pass directly to the auriculo-temporal nerve (p. 74).

On the lateral wall of the pharynx the glosso-pharyngeal nerve breaks up into lingual and pharyngeal branches. The **lingual branches** supply the mucous membrane of the posterior third of the tongue with ordinary sensation and with the sense of taste, and they extend to the soft palate and the palatine tonsil. In nuclear lesions of the tractus solitarius the sense of taste is not lost over the posterior part of the tongue. On account of the size of the tractus solitarius the results of lesions are very variable, but the escape of the taste fibres in such lesions has led many authorities to the view that these fibres pass to the sensory nucleus of the trigeminal, *via* the tympanic

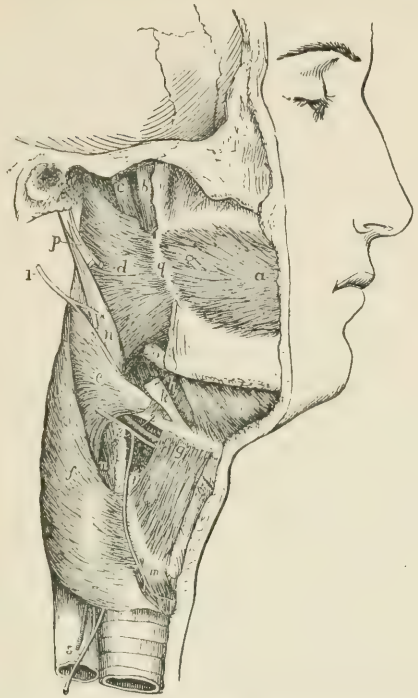


FIG. 48.—The Lateral Aspects of the Larynx and Pharynx, showing their Nerves of Supply.

NOTE.—In the upper part of the figure the right ramus of the mandible and the muscles (masseter, temporal and pterygoids) attached to it have been removed.

a. Buccinator.
b. Tensor veli palatini.
c. Levator veli palatini.
d. Superior constrictor.
e. Middle constrictor.
f. Inferior constrictor.
g. Thyreo-hyoid.
h. Hyo-glossus.
k. Stylo-hyoid.
l. Mylo-hyoid.
n. Stylo-pharyngeus.
p. Pharyngeal branch of vagus.
1. Glosso-pharyngeal nerve.
2. Superior laryngeal artery.
3. Superior laryngeal nerve.
4. External laryngeal nerve.
5. Recurrent (laryngeal) nerve.

nerve, the lesser superficial petrosal nerve, the otic ganglion and the mandibular nerve. The **pharyngeal branches** unite

with the pharyngeal branch of the vagus to form the pharyngeal plexus (p. 96). They supply sensory fibres to the mucous membrane of the pharynx and inhibitory fibres to the constrictor muscles.

The few *motor fibres* in the glosso-pharyngeal nerve supply the stylo-pharyngeus, which aids in the elevation of the thyreoid cartilage during the act of deglutition. It is possible that the motor fibres supplied to the tensor veli palatini by the otic ganglion (p. 70) are ultimately derived from the glosso-pharyngeal through the tympanic plexus (*vide supra*).

The glosso-pharyngeal nerve is never affected alone. The motor nucleus is involved in bulbar paralysis (p. 108) and the trunk of the nerve may be involved in syphilitic meningitis in the posterior cranial fossa, but, in both cases, the tenth and the eleventh nerves are also affected, owing to the close relationship which exists between the three nerves, as regards both their nuclei and their intra-cranial course (Figs. 35 and 47).

The **Vagus** or **Tenth Cerebral Nerve** possesses both motor and sensory fibres. The motor fibres arise from the *nucleus ambiguus*, an elongated column of grey matter which extends downwards through the medulla oblongata and becomes continuous with the anterior column of grey matter in the spinal medulla (Fig. 47).

The sensory fibres end partly in the *nucleus of the tractus solitarius* and partly in the *nucleus dorsalis*, which lies in the dorsal part of the medulla oblongata immediately under the lower part of the floor of the fourth ventricle (Fig. 47).

The emerging fibres of the vagus pass forwards through the medulla oblongata and appear in the groove between the olive and the restiform body, immediately below the rootlets of the glosso-pharyngeal nerve (Fig. 8).

Together with the latter and the accessory nerve, the vagus leaves the skull through the jugular foramen and, in this part of its course, it exhibits an enlargement, which is termed the *jugular ganglion*.

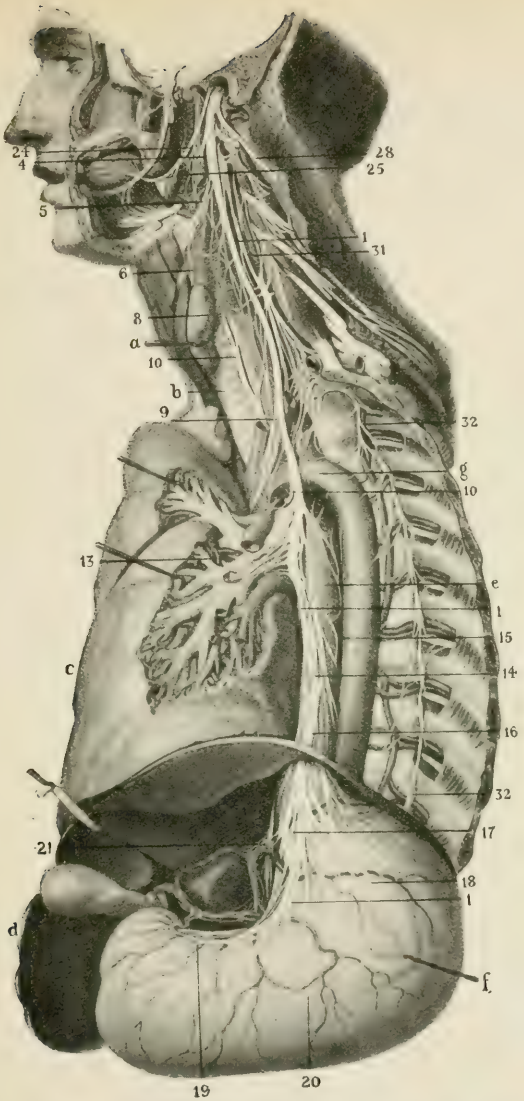


FIG. 49.—The Course, Relations and Branches of the Left Vagus Nerve.

1. Vagus nerve; 4. Pharyngeal branch; 5. Internal laryngeal nerve; 6. External laryngeal nerve; 8. Thyreoid gland; 9. Cardiac branches; 10. Recurrent (laryngeal) nerve; 13. Root of lung; 14, 15, 16. Œsophageal plexus; 17, 18, 19, 20. Gastric branches; 21. Hepatic branches; 24. Glosso-pharyngeal nerve; 25. Nerve to stylo-pharyngeus muscle; 28. Accessory nerve; 31, 32. Sympathetic trunk. *a*. Left lobe of thyreoid gland; *b*. Trachea; *c*. Left lung; *d*. Liver; *e*. Œsophagus; *f*. Stomach; *g*. Aortic arch.

The **auricular branch** of the vagus (**Arnold's nerve**) arises from the jugular ganglion and, having passed through a small canal in the petrous portion of the temporal bone, supplies branches to the skin which lines the lateral surface of the tympanic membrane and the deep part of the external acoustic meatus. This little nerve merits description because the stimulation of its terminal fibres may produce symptoms which are referred to the areas of distribution of the terminal branches of the vagus. Thus, a small piece of wax, impinging on the tympanic membrane, may be sufficient to set up gastric symptoms, which naturally do not respond to ordinary treatment. The condition of the ear is often overlooked, as there are no local symptoms to direct attention to the cause of the disorder (cf. p. 200).

Immediately below the skull a second peripheral ganglion, termed the *ganglion nodosum* (*ganglion of the trunk*), is placed on the vagus. At this point the vagus receives a large branch of communication, which represents the whole of that portion of the accessory nerve which takes origin in the medulla oblongata. The fibres contained in this communicating branch are entirely motor and they are destined, principally, for the supply of the muscles of the larynx and pharynx.

In addition, the ganglion nodosum establishes communications with the hypoglossal nerve, the first cervical nerve and the superior cervical ganglion of the sympathetic trunk, but the explanation of these connexions is not known.

The **pharyngeal branch** of the vagus arises from the ganglion nodosum and assists the glosso-pharyngeal nerve in the formation of the *pharyngeal plexus*. Through the plexus the vagus nerve supplies motor branches, not only to the constrictor muscles of the pharynx, but also to the muscles of the soft palate, with the possible exception of the tensor veli palatini (p. 70).

In bilateral lesions of the lower neurone (*e.g.* in post-diphtheritic neuritis of the vagus or in bulbar paralysis, p. 108) difficulty in swallowing is very pronounced, as the muscular

walls of the pharynx fail to grip the bolus of food and to help it on its way to the œsophagus. In addition, the soft palate is paralysed, and on this account the naso-pharynx is not shut off from the oral pharynx during deglutition. As a result, the food, taking the path of least resistance, regurgitates through the nose. A further result of the palatal paralysis is an alteration in the character of the voice, which acquires a distinctly nasal tone.

The **superior laryngeal nerve** leaves the vagus at the lower end of the ganglion nodosum and passes downwards and medially towards the larynx. It breaks up into the internal and external laryngeal nerves.

The **internal laryngeal nerve** contains sensory fibres only. It enters the larynx through the lateral part of the thyreo-hyoid membrane and supplies the mucous membrane of the interior above the level of the vocal folds (true vocal cords). A few of its fibres are distributed also to the mucous membrane of the recessus piriformis (p. 332). Stimulation of the terminal branches of the internal laryngeal nerve sets up the *cough reflex*, and, on this account, the lodgment of a particle of food in the recessus piriformis causes a severe spasm of coughing, the patient experiencing sensations similar to those induced by irritation of the interior of the larynx.

The **external laryngeal nerve** is a purely motor nerve, which descends in company with the superior thyreoid artery and passes under cover of the upper pole of the lateral lobe of the thyreoid gland. It gives off one or two small branches to the inferior constrictor muscle of the pharynx, but it is mainly reserved for the supply of the *crico-thyreoid*. The contraction of this muscle puts the vocal folds (true vocal cords) on the stretch, and, when it is paralysed, the pitch of the voice is lowered, as the other laryngeal muscles cannot maintain the requisite tension (p. 339).

In the neck the vagus descends vertically in the posterior part of the cartoid sheath, in which it lies between the internal jugular vein and the common carotid artery.

Cardiac branches arise from both vagi in the neck and from the right vagus and left recurrent (laryngeal) nerves in the thorax. These branches constitute the *inhibitory nerves of the heart*, and they are, therefore, antagonistic to the cardiac

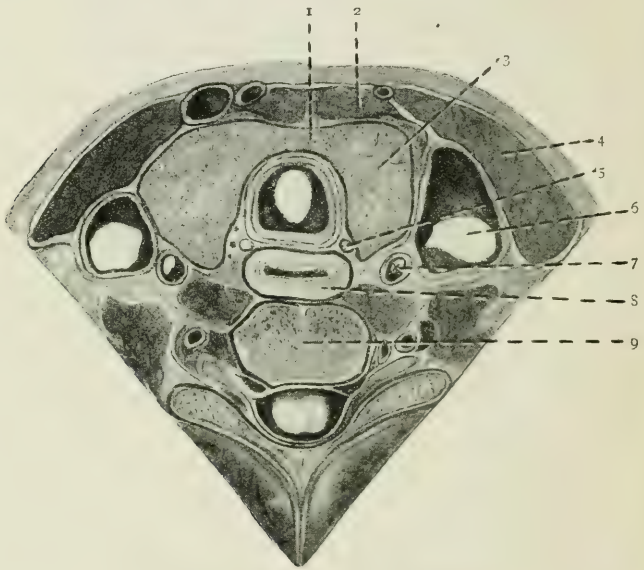


FIG. 50.—Transverse Section through the Neck at the level of the First Thoracic Vertebra.

1. Isthmus of thyreoid gland.
2. Sterno-hyoid and sterno-thyreoid muscles.
3. Right lobe of thyreoid gland.
4. Sterno-mastoid muscle.
5. Right recurrent nerve.
6. Internal jugular vein.
7. Common carotid artery.
8. Œsophagus.
9. First thoracic vertebra.

branches from the sympathetic, which act as accelerators of the heart-rate. UNILATERAL LESIONS of the vagus cause only a transitory disturbance of the heart's action, but BILATERAL LESIONS produce a profound effect. Irritative lesions, such as occur in the early stages of post-diphtheritic neuritis, stimulate

the inhibitory fibres and lead to a slowing of the heart-rate, whereas vagal paralysis is followed by definite acceleration of the rate, since the sympathetic fibres are no longer opposed.

The **recurrent (laryngeal) nerves** arise at different levels on the two sides of the body. The *right recurrent nerve* leaves the vagus as it crosses the subclavian artery at the root of the neck. It hooks round behind the termination of the innominate artery and then ascends in the groove between the œsophagus and the trachea (Fig. 50), where it comes into close contact with the lateral lobe of the thyreoid gland.

The *left recurrent nerve* arises from the vagus as it crosses the arch of the aorta in the thorax. It passes backwards below the aortic arch and then upwards behind it. In the first part of its course the left recurrent nerve lies a little above the left bronchus and it may be compressed against the aortic arch, when the bronchus is displaced upwards by enlargement of the left atrium (auricle) of the heart in mitral stenosis. It then ascends through the thorax in the groove on the left side of the trachea (p. 339) and enters the neck, where its relations are similar to those already described for the recurrent nerve of the right side.

The recurrent nerve supplies most of the intrinsic muscles of the larynx, and its sensory fibres are distributed to the laryngeal mucous membrane below the level of the vocal folds (true vocal cords).

Owing to its longer course, the left recurrent nerve is subjected to pressure more often than the right. It may be compressed—(1) By aneurisms of the aortic arch (p. 319); (2) by mediastinal tumours or enlarged mediastinal lymph glands; (3) by the left bronchus (*vide supra*). The right recurrent may be compressed near its origin by aneurism of the terminal part of the innominate artery. Lastly, either or both nerves may be affected in enlargements of the thyreoid gland.

The various results of paralysis of the recurrent nerves are described on page 338.

Within the thorax, the right vagus descends on the right side of the trachea and then passes behind the root of the right lung. In this part of its course, it is exposed to pressure from mediastinal tumours or enlarged mediastinal lymph glands. The left vagus crosses the left or anterior aspect of the arch of the aorta and then passes behind the root of the left lung. Both vagi assist in the formation of the pulmonary plexuses, in which they unite with branches from the sympathetic. The pulmonary branches of the vagi are said to supply the circular muscular coats of the bronchi, and they are believed by some authorities to be at fault in the condition of spasmodic asthma.

On leaving the roots of the lungs, the two vagi pass downwards on the œsophagus and form the œsophageal plexus. They leave the thorax in company with the œsophagus and enter the abdomen, where their terminal branches are distributed to the stomach and, probably, also to the liver and the small intestine.

Summary.—The vagus nerve, therefore, is responsible for the *motor supply* of—(1) The soft palate; (2) the pharyngeal muscles; (3) the laryngeal muscles; (4) the heart—inhibitory; (5) the œsophagus, stomach, etc.; and (6) the bronchial muscles (?). It conveys *afferent* impulses from—(1) The stomach and œsophagus; (2) the heart; (3) the larynx, bronchi and lungs; and (4) the external acoustic meatus (p. 199).

All these structures may be affected in lesions of the nerve or its nuclei (p. 94); and any one of them may be affected reflexly in pathological conditions of one of the others (cf. pp. 190 and 195).

Supra-nuclear Lesions produce no noticeable effects, unless they are bilateral. Any paresis that may exist is completely masked, owing to bilateral representation of the muscles in the cerebral cortex (p. 34).

Nuclear Lesions are of fairly common occurrence. They are usually bilateral and constitute a part of a slowly progressive

condition, which is termed bulbar paralysis. Reference is made to this condition on page 108.

Infra-nuclear Lesions, when *bilateral* as in post-diphtheritic neuritis, result in complete paralysis of the muscles supplied by the vagi. The constrictors of the pharynx and the muscles of the soft palate are affected, causing difficulty in swallowing and in pronunciation (p. 108). The ary-epiglottic muscles (p. 332) may be involved, and, if so, there is grave danger of inspiration pneumonia. Owing to paralysis of the cardiac inhibitory nerves, the rate of the heart's action becomes greatly accelerated. The effects on the lungs, œsophagus and stomach are not easily determinable, but they would appear to be relatively of little importance.

Unilateral Lesions may affect the vagus in its course from the medulla oblongata to the jugular foramen, and they are usually caused by inflammatory conditions of the dura mater. The glosso-pharyngeal, the accessory and, probably, the hypoglossal nerves will be affected at the same time (Fig. 51), but the direct results of this extensive paralysis are not so serious as might be expected, because a good degree of compensation is obtained, owing to overaction of the lingual, palatal, pharyngeal and laryngeal muscles of the sound side.

The vagus nerve may be affected alone below the level of the greater cornu of the hyoid bone. If the lesion occurs above the point of origin of the recurrent (laryngeal) nerve, the symptoms are precisely the same as are found in lesions of that nerve (p. 338). When the vagus is involved below the origin of the recurrent nerve, no characteristic symptoms are produced.

The **Accessory** or **Eleventh Cerebral Nerve** is purely motor in function. It consists of a *cerebral* and a *spinal portion*, but the two are only related intimately as they pass through the jugular foramen.

The **cerebral portion** arises from the lower part of the *nucleus ambiguus* (p. 94), and its fibres emerge from the medulla

oblongata in the lower part of the groove between the olive and the restiform body. After leaving the skull, it joins the

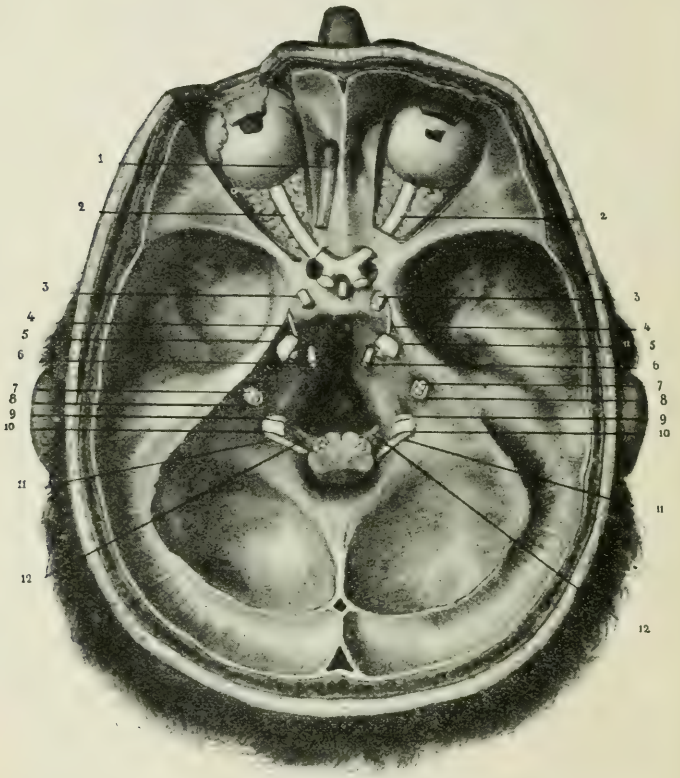


FIG. 51.—Interior of the Skull after the removal of the Brain, showing the points of exit of the twelve cerebral nerves.

ganglion nodosum of the vagus, and it should really be considered as a part of the vagus nerve (p. 96).

The **spinal portion** arises from the anterior column of grey matter in the spinal medulla, and its rootlets emerge on the

lateral aspect of the spinal medulla, midway between the anterior and posterior roots of the upper five cervical nerves. They ascend in the vertebral canal, forming a common trunk, which enters the cranium through the foramen magnum and passes to the jugular foramen. Outside the skull the spinal portion of the accessory runs downwards, backwards and laterally through the neck (Fig. 49), and it is entirely distributed to the *sterno-mastoid* and the upper part of the *trapezius*.

The *sterno-mastoid* arises from the manubrium sterni and the medial third of the clavicle and passes upwards, backwards and laterally to be inserted into the mastoid process and the occipital bone. Contraction of the muscle approximates its insertion to its origin, and therefore the mastoid process is approximated to the manubrium, *i.e.* the head is rotated towards the opposite side and, at the same time, the chin is tilted upwards.

The *upper part of the trapezius* arises from the external occipital protuberance and the ligamentum nuchæ, and its fibres pass downwards and laterally to be inserted into the lateral third of the clavicle. When the muscle contracts, it elevates the point of the shoulder and, in association with the serratus anterior (s. magnus), rotates the scapula clockwise (as viewed from in front), enabling the arm to be flexed and abducted beyond a right angle (p. 132). Further, when the body is in the erect or sitting posture with the arms unsupported, the weight of the upper limb is partially borne by the upper portion of the trapezius.

Supra-nuclear Lesions of the fibres of the spinal portion of the accessory nerve are never isolated, and occur most commonly in cerebral hemiplegia in company with extensive paralysis of the limb muscles. The sterno-mastoid, though weakened, is not paralysed, since it is innervated from the cortex of both cerebral hemispheres. The upper part of the trapezius is not completely paralysed, but the point of the shoulder, being depressed by the weight of the limb, occupies a lower level than the point of the sound shoulder.

Nuclear Lesions occur in the late stages of progressive muscular atrophy or as the result of a downward spread in bulbar paralysis (p. 108). Since the lesion is bilateral, both the sterno-mastoids and both the trapezius muscles are paralysed. The head therefore falls forward and cannot be extended on the trunk. This condition, however, is not wholly referable to the trapezius, as the deeper muscles at the back of the neck are also involved.

Infra-nuclear Lesions of the accessory nerve may occur (*a*) in the anterior triangle of the neck, and (*b*) in the posterior triangle.

(*a*) Neuritis of the accessory gives rise to the condition of spasmodic torticollis, which is due to spasmodic contraction of the sterno-mastoid, on the side of the lesion. This condition may be accompanied by spasm of the upper fibres of the trapezius, resulting in spasmodic elevations of the point of the shoulder, which synchronise with the torticollis.

Paralysis of the sterno-mastoid is marked by tonic torticollis, which is not always pronounced, but in this case the condition is due to the tonus of the unopposed muscle of the sound side.

When the trapezius is paralysed, the point of the shoulder on the affected side drops to a lower level, because, under normal conditions, the upper part of the muscle helps to support the weight of the upper limb. In addition, since the lower neurone is affected, the muscles atrophy and exhibit alterations in their electrical excitability. Owing to atrophy of the trapezius, the normal rounded contour of the side of the neck is lost and the resulting "square" appearance is quite characteristic.

(*b*) When the accessory nerve is injured in its course across the posterior triangle, only the trapezius is affected. As the injury is commonly caused by heavy weights, carried on the shoulder, the *long thoracic nerve* (*of Bell*) may also be involved and the deformity is more complicated (p. 133).

The **Hypoglossal or Twelfth Cerebral Nerve** is purely

motor in function. It arises from a nucleus which is situated in the dorsal part of the medulla oblongata (Fig. 52) and which is continuous below with the anterior column of grey matter in the spinal medulla. The fibres pass forwards through the substance of the medulla oblongata and come into close relationship with the pyramidal tract, before they emerge from the groove between the pyramid and the olive (Fig. 8). As it runs laterally from the medulla oblongata, the hypoglossal nerve lies below the ninth, tenth and eleventh nerves in the posterior cranial fossa. It passes through the hypo-

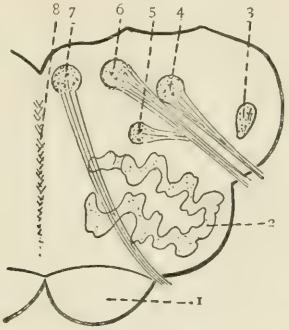


FIG. 52.—Section through Upper Part of Medulla Oblongata.

1. Pyramidal tract. 2. Olivary nucleus. 7. Nucleus of hypoglossal nerve.

glossal canal (anterior condyloid foramen), which pierces the occipital bone just above the condyle. Consequently, after leaving the skull, the nerve descends close to the lateral aspect of the atlanto-occipital joint. On this account, it may be involved in tuberculous disease of the articulation, and paralysis and atrophy of one half of the tongue is a valuable localising symptom in cervical caries.

In its extra-cranial course, the hypoglossal nerve is at first related to the ninth, tenth and eleventh nerves, but it passes forwards on a level with the greater cornu of the hyoid bone to reach the tongue.

In the upper part of the neck, the hypoglossal nerve receives a branch of communication from the anterior ramus (primary division) of the first cervical nerve. This communication leaves the nerve in three parts, which are all distributed to muscles acting on the hyoid bone. The first part constitutes the **ramus descendens hypoglossi,** which unites with the **ramus descendens cervicalis** (C. 2 and 3) to form the **ansa hypoglossi.** From the loop thus formed the sterno-hyoid, the sterno-thyreoid and the omo-hyoid muscles receive their nerve supply. The second part supplies the thyreo-hyoid; the third part is distributed to the genio-hyoid.

The *sterno-thyreoid* passes upwards from the posterior aspect of the manubrium sterni to the lateral aspect of the thyreoid cartilage and, as it ascends, it covers the lateral lobe of the thyreoid gland.

The *sterno-hyoid* covers the medial part of the sterno-thyreoid and extends upwards to the hyoid bone.

The *omo-hyoid* is a digastric muscle. Its *posterior belly* runs medially from the upper border of the scapula and, under cover of the sterno-mastoid, ends in the common tendon, which is held down to the medial end of the clavicle by a slip of the deep cervical fascia. Its anterior belly runs upwards, superficial to the sterno-thyreoid and along the lateral border of the sterno-hyoid, to reach the hyoid bone.

The *thyreo-hyoid* may be regarded as the upward continuation of the sterno-thyreoid to the hyoid bone.

These four muscles depress the hyoid bone and larynx in the last stage of the act of deglutition, and they have a steadying action when these structures are being elevated.

Paralysis of this group, combined with paralysis of the tongue on the same side, is symptomatic of a lesion of the hypoglossal nerve in the first part of its extra-cranial course. Owing to paralysis of the depressors, the tonus of the unopposed elevators (mylo-hyoid and digastric) causes the greater cornu of the hyoid bone to lie at a higher level on the side of the lesion. When the muscles become atrophied, the condition is readily recognised on palpation of the thyreoid cartilage.

The *genio-hyoids* are two short muscles which extend from the deep surface of the mandible at the symphysis to the hyoid bone. They lie deep to the mylo-hyoids and aid them in elevating the hyoid bone and larynx.

The *terminal branches* of the hypoglossal nerve are distributed to the muscles of the tongue. This group includes the stylo-glossus, the hyo-glossus, the genio-glossus and the intrinsic muscles.

The fibres which are distributed by the facial nerve to the orbicularis oris muscle are said to arise in the hypoglossal nucleus. They then ascend to join the facial nerve of the same side (p. 87).

Supra-nuclear Lesions produce little effect on the tongue muscles, owing to their bilateral representation in the cerebral cortex. If they occur in the internal capsule, a true deviation of the protruded tongue may be present, owing to weakening of the genio-glossus (*vide infra*).

Nuclear Lesions are usually bilateral (bulbar paralysis, p. 108). The tongue lies motionless in the floor of the mouth and deglutition is, therefore, practically impossible. The orbicularis oris is also affected, and the combined paralysis of tongue and lips has a serious effect on the speech.

Infra-nuclear Lesions.—In rare cases, the fibres of the hypoglossal may be interfered with as they traverse the medulla oblongata. The site of the lesion is usually indicated by a crossed paralysis, the limbs being affected on the opposite side of the body, owing to injury of the pyramidal tract above the decussation (Fig. 52).

In unilateral hypoglossal paralysis, the characteristic sign is deviation of the protruded tongue to the paralysed side. This is principally due to the action of the unopposed *genio-glossus* of the sound side, which arises from the posterior aspect of the symphysis menti and spreads backwards and laterally into the tongue. Owing to the lateral inclination of some of its fibres, the unopposed genio-glossus drags the lateral border of the dorsum of the tongue towards the median plane and thus the tongue, as a whole, is pulled over to the side of the lesion. Difficulty in the pronunciation of the lingual consonants also accompanies unilateral paralysis of the tongue muscles, and speech is therefore rendered indistinct.

Bulbar Paralysis.—As the motor nuclei of the ninth, tenth, twelfth and the cerebral portion of the eleventh are intimately related to one another in the medulla oblongata (Fig. 52), it is not surprising to find that they may all be involved in certain, slowly progressive, degenerative processes. Further, as the nucleus ambiguus (p. 94) and the hypoglossal nucleus represent the upward continuation of the anterior column of the grey matter of the spinal medulla, the spread of the process from the one to the other is of common occurrence.

The term *bulbar paralysis* is applied to lesions affecting the motor nuclei of the medulla oblongata, whether they occur as the starting-point of a downward spreading process or in the later stages of an upward spreading process, *e.g.* progressive muscular atrophy (p. 46). The symptoms vary in different cases, as the disease does not attack the groups of cells within the nuclei in any fixed order.

As a rule, the hypoglossal nuclei are first involved, and weakness of the tongue muscles and the orbicularis oris (p. 107), causing difficulties in speech and deglutition, are often the first signs that a case of progressive muscular atrophy has entered on its last stage. Later, the muscles of the pharynx and soft palate are involved and the patient becomes unable to swallow. Paralysis of the laryngeal muscles is not usually very noticeable, but, when the ary-epiglottici (p. 332) are affected early there is grave danger of aspiration pneumonia.

The same symptoms may arise suddenly, owing to small hæmorrhages or areas of embolic softening in the medulla oblongata. The distinctive term "acute bulbar paralysis" has been given to this condition.

THE MEMBRANES OF THE BRAIN

The brain is surrounded by three membranous layers, termed the dura mater, the arachnoid and the pia mater. The spaces separating these membranes from one another

contain a clear serous fluid (p. 23), which serves to protect the brain from laceration and contusion.

The **Dura Mater** constitutes the outermost covering and is the strongest of the three membranes which invest the brain. It is usually described as consisting of an *inner, serous* and an *outer, fibrous layer*, but the latter is really the endoperiosteum, which lines the cranial cavity and is everywhere closely applied to the bone, being specially adherent to the floor of the skull.

The **serous layer** of the dura mater lines the cavity in which the brain lies, and it is separated from the arachnoid by the subdural space, which contains the clear, subdural fluid. No communications exist between the subdural and the subarachnoid spaces, and the passage of fluid from one space to the other occurs by a process of osmosis through the arachnoid. There is no marked difference between the subdural fluid and the cerebro-spinal fluid, which is found in the subarachnoid space, and it is therefore immaterial which of the two is drawn off for examination in a lumbar puncture (p. 41). In fractures of the skull, the discharge of serous fluid from the nose or acoustic meatus indicates that the serous layer of the dura mater has been injured.

The **falx cerebri** is a longitudinal crescentic fold of the serous layer. It dips into the longitudinal fissure and partially separates the two cerebral hemispheres from one another. Its anterior extremity is attached to the ethmoid bone, but its intermediate portion has a free lower margin, which overhangs the corpus callosum. Posteriorly, the two layers of the falx cerebri are continuous, on each side, with the upper layer of the tentorium cerebelli (Fig. 53).

The **tentorium cerebelli** is a transverse fold of the serous layer, which projects into the posterior part of the cranial cavity from behind and from the sides. It forms a partition which separates the cerebellum below from the cerebral hemispheres above. Its peripheral border is attached to the upper margin of the posterior cranial fossa, but its anterior

border is free, and, together with the dorsum sellæ of the sphenoid bone, bounds an aperture through which the mid-brain passes to reach the cerebrum (Fig. 53).

The **Arachnoid** is a much more delicate membrane than the dura mater, and it differs still further from the latter in being more intimately related to the brain.

The **Pia Mater**, which lies subjacent to the arachnoid, dips

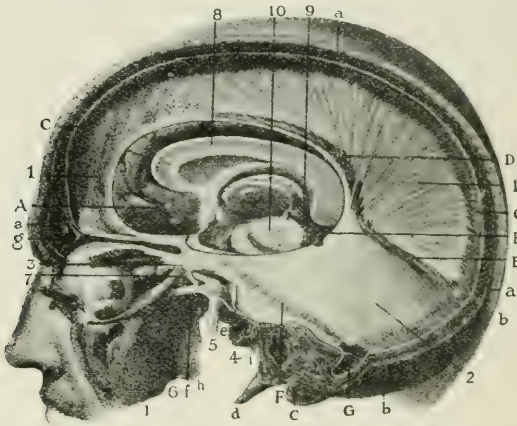


FIG. 53.—The Cranial Blood Sinuses. The left half of the skull and the left cerebral hemisphere have been removed.

1. Falx cerebri. | 2. Tentorium cerebelli.

into all the sulci on the surface of the brain, but the arachnoid merely bridges over their margins. Over the various convolutions the two membranes are closely applied to one another, and in these areas the subarachnoid space is practically obliterated. In certain areas, however, definite intervals exist between the arachnoid and the pia mater. These parts of the subarachnoid space are termed *cisternæ*, and the more important of them are situated on the basal surface of the brain.

The *cisterna interpeduncularis* (*basalis*) lies over the interpeduncular fossa and it contains the third, fourth and sixth cerebral nerves, and the optic tracts in a part of their course. In basal meningitis, purulent exudates are found in the cisternæ and, when the cisterna interpeduncularis is implicated, ocular paralysis or visual disturbances are of common occurrence.

The *cisterna fossæ lateralis cerebri* lies in relation to the anterior perforated substance (p. 16) and contains the middle cerebral artery. It is through this cisterna that the purulent exudate spreads to the lateral surface of the brain in tuberculous basal meningitis.

The *cisterna cerebello-medullaris* (*c. magna*) lies between the cerebellum and the lower part of the roof of the fourth ventricle. In this region the roof is extremely thin and consists of ependyma and the covering pia mater. The cisterna cerebello-medullaris communicates with the interior of the ventricular system through three small foramina, which pierce the thin roof and, as a result of these communications, the cerebro-spinal fluid (p. 23) is able to drain away into the subarachnoid space. When the foramina are closed by adhesions, as may happen following meningitis, this outlet is shut off and the fluid accumulates within the ventricles, giving rise to *acquired hydrocephalus*. It is also owing to these communications that turbulent fluid is frequently found inside the ventricles in association with the presence of purulent exudates in the subarachnoid space.

A small, unnamed cisterna lies over the "cerebello pontine angle" (p. 22) and it is traversed by the fifth, seventh and eighth cerebral nerves. This cisterna is a favourite site for purulent exudations in cerebro-spinal meningitis, and, therefore, paralysis of the nerves mentioned is a not uncommon sequela of the disease.

The **Cranial Blood Sinuses** are placed between the serous layer of the dura mater and the endo-periosteum of the skull.

The additional support which they gain in this way is required, for their walls are extremely thin and consist of little more than a lining of endothelium. On this account severe hæmorrhage occurs when a sinus is wounded, as its walls do not collapse like those of other veins. The cranial

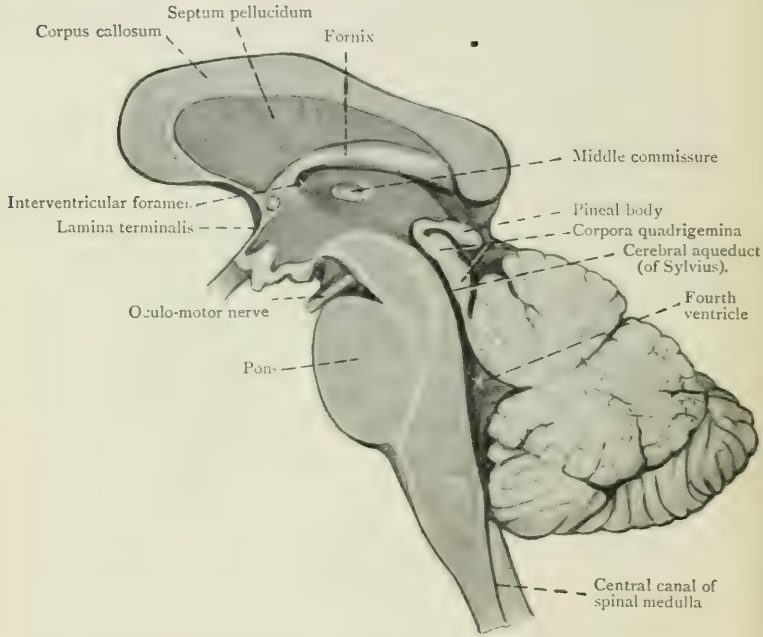


FIG. 54.—Median Sagittal Section through the Brain-Stem, showing the third and fourth ventricles and their connexions.

sinuses establish numerous connexions with the veins outside the skull, and these communications are of great practical importance, because, as they possess no valves, they afford channels for the spread of septic thrombi.

The **Superior Sagittal (Longitudinal) Sinus** lies in the upper border of the falx cerebri. It begins anteriorly at the

foramen cæcum of the ethmoid, through which it may communicate with the veins of the nasal mucous membrane. Owing to this communication, epistaxis may occur in children,

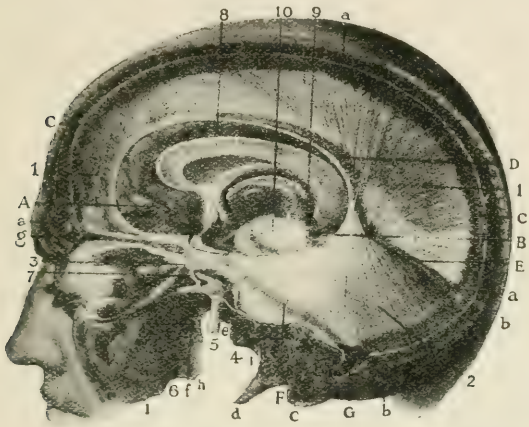


FIG. 55.—The Cranial Blood Sinuses. The left half of the skull and the left cerebral hemisphere have been removed.

A. Anterior cerebral artery.
B. Great cerebral vein (of Galen).
C. Superior sagittal sinus.
D. Inferior sagittal sinus.
E. Straight sinus.
F. Superior petrosal sinus.
G. Transverse (lateral) sinus.
a. Scalp.
b. Cut edge of skull.
c. Mastoid process.
d. Styloid process.
e. Foramen ovale.
f. Maxillary nerve.
g. Frontal air sinus.
h. Lateral pterygoid lamina.
j. Mandibular (glenoid) fossa.
l. Maxilla.
1. Falx cerebri.
2. Tentorium cerebelli.
3. Optic nerve.
4. Cut edge of dura mater.
5. Mandibular nerve.
6. Tuberosity of maxilla.
7. Ophthalmic nerve.
8. Corpus callosum.
9. Pineal body.
10. Mid-brain.

following an increase of intra-cranial tension such as accompanies a fit of temper. The foramen cæcum is usually patent in young children, but it may become closed at a later stage.

The superior sagittal sinus passes backwards and, at the posterior end of the falx cerebri, it reaches the internal occipital protuberance, where it bends sharply, usually to the right, to form the transverse (lateral) sinus. In its course, the superior sagittal sinus receives numerous tributaries from the surface of the brain and, through a foramen in each parietal bone, it communicates with the veins of the scalp. Through this connexion septic infections of the scalp may give rise to thrombosis of the sinus.

The **Inferior Sagittal (Longitudinal) Sinus** lies in the free, lower border of the falx cerebri and, at its posterior end, unites with the great cerebral vein (of Galen, p. 27) to form the straight sinus. It receives tributaries from the medial surfaces of the cerebral hemispheres.

The **Straight Sinus** runs backwards over the upper surface of the tentorium cerebelli in the lower border of the falx cerebri, until it reaches the internal occipital protuberance, where it bends sharply, usually to the left, to form the transverse (lateral) sinus. It receives tributaries from the occipital lobes and from the cerebellum.

The **Transverse (Lateral) Sinus** of the right side is continuous with the superior sagittal sinus, while that of the left side is continuous with the straight sinus. It begins at the internal occipital protuberance and runs laterally in the attached, peripheral border of the tentorium cerebelli. When it reaches the mastoid part of the temporal bone, it passes downwards, forming a deep groove in the side wall of the posterior cranial fossa. In this part of its course, the transverse sinus lies behind the *tympanic* (*mastoid*) *antrum,* which is contained within the posterior part of the petrous temporal, and it communicates with the posterior auricular vein of the scalp through the mastoid foramen. Finally, it passes through the jugular foramen and becomes continuous with the internal jugular vein.

The transverse sinus is joined by the *superior petrosal sinus*, which connects it to the cavernous sinus, and by

numerous cerebral and cerebellar veins. On account of its proximity to the tympanic (mastoid) antrum, the sinus may become the site of a septic thrombus in inflammatory conditions of the antrum, and the infection may spread backwards along the cerebellar veins, ultimately giving rise to a *cerebellar abscess.*

The **Cavernous Sinuses** lie one on each side of the body of the sphenoid in the middle cranial fossa. At its anterior end,

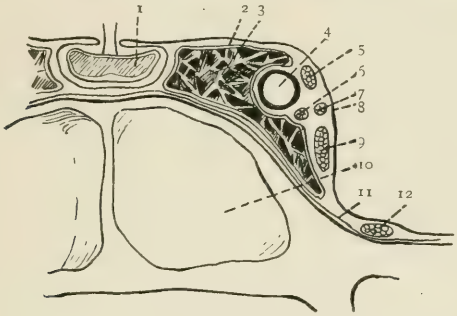


FIG. 56.—Transverse Section through the Cavernous Sinus.

1. Hypophysis.
2. Endothelial wall of sinus.
3. Cavernous sinus.
4. Internal carotid artery.
5. Oculo-motor nerve.
6. Abducent nerve.
7. Trochlear nerve.
8. Serous layer of dura mater.
9. Ophthalmic nerve.
10. Sphenoidal air-sinus.
11. Endo-periosteum of skull.
12. Maxillary nerve.

each sinus receives the ophthalmic veins, which bring it into communication, indirectly, with the veins of the face. From its posterior end, the *superior* and *inferior petrosal sinuses* pass backwards to join, respectively, the transverse sinus and the internal jugular vein. In addition, each cavernous sinus communicates with the veins of the pterygoid plexus through the foramen ovale and through the foramen of Vesalius, when the latter is present. The pterygoid veins are tributaries of the internal maxillary vein, which receives all the alveolar (dental) and a few pharyngeal veins. In this way the latter

groups are brought into communication with the cavernous sinus.

Owing to its numerous communications, the cavernous sinus may become the site of a septic thrombosis following infective processes of the face, orbit, teeth or naso-pharynx. The condition is usually accompanied by paralyses of the ocular muscles and there may be sensory disturbances over the area supplied by the ophthalmic nerve (Fig. 41). These complications are due to the intimate relation which the third, fourth, sixth and ophthalmic nerves bear to the cavernous sinus, for, after they pierce the serous layer of the dura mater and before they enter the orbit, they lie in the lateral wall of the sinus, between the supporting dura mater and the lining endothelium (Fig. 56).

The Blood-supply of the Brain and its Membranes.—The dura mater receives its blood-supply from the meningeal arteries, which are placed between the endo-periosteum and the serous layer. Of these the most important is the **middle meningeal artery.** It arises from the internal maxillary artery, which is one of the terminal branches of the external carotid, and, entering the skull through the foramen spinosum, runs forwards and laterally over the floor of the middle cranial fossa. Its *anterior branch* runs upwards towards the vertex along a line which may be said to correspond to the pre-central sulcus (Fig. 3), and, when it is torn, the resulting blood-clot exercises pressure on the neighbouring anterior central gyrus (p. 5). The area involved and, consequently, the symptoms will depend on the site of the clot, but, owing to their position, the motor centres for the lower limb (p. 5) are never affected in the first instance. Unless the dura mater is ruptured, the hæmorrhage is extra-dural in position.

The *posterior branch* of the middle meningeal artery runs backwards along a line which lies a little above the level of the middle temporal sulcus. Rupture of this division will not,

in the first instance, produce any motor paralysis, but it will lead to pressure on the higher auditory centres. These effects, however, cannot be recognised owing to the accompanying loss of consciousness.

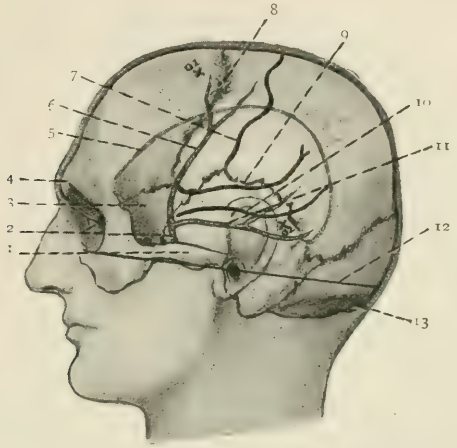


FIG. 57.—Lateral Aspect of Skull, showing the relations of important structures to the surface.

1. Zygomatic arch.
2. Middle meningeal artery.
3. Greater wing of sphenoid.
4. Glabella.
5. Temporal line.
6. Anterior branch of middle meningeal artery.
7. Central sulcus (of Rolando).
8 Coronal suture.
9 Lateral fissure, posterior ramus.
10. Superior temporal sulcus.
11. Posterior branch of middle meningeal artery.
12. Line drawn from floor of orbit through centre of external acoustic meatus.
13. External occipital protuberance.
o^1. Site for puncture of lateral ventricle.
o^2. Site for puncture of inferior horn of lateral ventricle.]

The walls of the **meningeal veins** are very similar in structure to the walls of the cranial blood sinuses, and they consist of an endothelial layer and a slight amount of supporting fibrous tissue. On this account they are easily torn, and in most cases meningeal hæmorrhage has its source in the veins and not in the arteries.

The Cerebral Arteries.—Four large arteries enter the cranial cavity to supply the brain, and in the neighbourhood

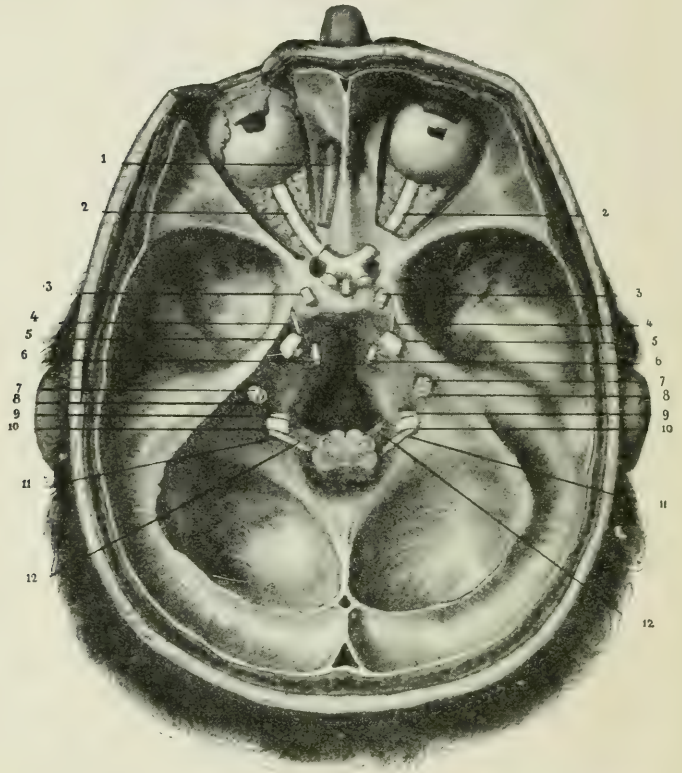


FIG. 58.—Interior of the Skull after the removal of the Brain, showing the points of exit of the twelve cerebral nerves.

of the interpeduncular fossa they become interconnected so as to form the *arterial circle* (*of Willis*).

The **Internal Carotid Artery** enters the skull through a special canal in the petrous temporal and passes forwards in

the lateral wall of the cavernous sinus, lying between the endoperiosteum and the endothelial lining. At the anterior clinoid process (Fig. 58) it pierces the dura mater and, opposite the anterior perforated substance (spot), it ends by dividing into the anterior and middle cerebral arteries.

The *Middle Cerebral Artery* inclines laterally across the anterior perforated substance and enters the lateral fissure (of Sylvius). It then courses over the surface of the island (of Reil) and extends backwards in the posterior ramus of the lateral fissure. It gives off a number of *cortical branches*, which emerge from the fissure and supply the whole of the lateral surface of the hemisphere, with the exception of a strip along its superior and inferior margins. Further, they do not supply the occipital lobe. The middle cerebral artery, therefore, supplies—(1) The whole of the motor area, except the lower limb centres; (2) the motor speech centre; (3) the centre for written speech; (4) the word-hearing centre; and (5) the word-seeing centre (Fig. 3).

As it crosses the anterior perforated substance, the middle cerebral artery gives off several *central branches*, which at once pass upwards and enter the brain. They thus come into relationship with the lentiform nucleus (p. 33) and they ascend across its lateral surface for a short distance before they pass medially into its substance. The *lenticulo striate arteries* traverse the anterior part of the lentiform nucleus and the anterior limb of the internal capsule and terminate in the head of the caudate nucleus. The *lenticulo-optic arteries* are placed more posteriorly, and consequently pass through the posterior limb of the internal capsule before they reach the thalamus. The artery of cerebral hæmorrhage belongs to the former group.

The central arteries, as they lie in the brain substance, are poorly supported and they are, in consequence, frequently the site of small aneurismal dilatations. When small emboli are carried into the middle cerebral artery, they are usually arrested in the cortical branches and only rarely enter the

central branches, owing to the upward course which these arteries take.

The *Anterior Cerebral Artery*, at its origin from the internal carotid, at once bends abruptly in a medial direction to gain the posterior extremity of the longitudinal fissure. It then bends sharply forwards and is continued round the genu of the corpus callosum in company with the artery of the opposite side. Together they extend backwards at the bottom of the longitudinal fissure until they reach the parietal lobes.

The anterior cerebral artery is responsible for the supply of the whole of the medial aspect of the hemisphere as far back as the precuneus, and, in addition, its cortical branches emerge from the longitudinal fissure to supply the cortex of the lateral and orbital aspects near their margins. The anterior cerebral artery, therefore, supplies the upper extremity of the precentral gyrus, which contains the motor centres for the lower limb.

The **Vertebral Artery**, which arises from the first part of the subclavian in the root of the neck, passes upwards, traversing the foramina in the transverse processes of the cervical vertebræ, and enters the skull through the foramen magnum. Within the skull, it ascends on the lateral aspect of the medulla oblongata and inclines medially to meet its fellow of the opposite side in the median plane at the lower border of the pons. At this point the two vertebral arteries unite to form the **Basilar Artery**, which passes upwards in the median plane to the upper border of the pons, where it divides into the two posterior cerebral arteries.

The *Posterior Cerebral Artery* runs laterally and backwards round the mid-brain, to which it supplies *central branches*. Its *cortical branches* are distributed to the posterior two-thirds of the inferior surface of the cerebral hemisphere, and, in addition, they supply the cortex of the whole of the occipital lobe. The posterior cerebral artery is, therefore, responsible for the blood-supply of the higher visual centres, and, on this account, an embolus which finds its way into

this artery gives rise to the condition of homonymous hemianopia (p. 52).

The **Arterial Circle (of Willis)** brings the six cerebral arteries into communication with one another. As the two anterior cerebrals lie side by side in the longitudinal fissure, they are connected to one another by the anterior communicating artery, which thus links up the two carotid systems. Each internal carotid artery is connected to the posterior cerebral of its own side by the posterior communicating artery, and thus the two carotid systems are linked up with the basilar system. This arterial anastomosis provides a means for the re-establishment of the circulation when any of the great cerebral blood-vessels is obstructed outside the skull.

When emboli are carried along the internal carotid artery into the skull, they usually pass into the middle cerebral artery, owing to the abrupt bend which the anterior cerebral makes at its origin. In cortical lesions due to this cause, the prognosis is good and almost complete recovery may be expected, because the cortical branches of the cerebral arteries anastomose with one another, although not with any degree of freedom On the other hand, the central branches are all end-arteries, *i.e.* they do not establish any anastomoses with one another, and, on this account, obstruction to the blood-supply of any central area will, unless very transient, always be followed by necrosis of practically the whole of that area.

The **Veins of the Brain** are divided into a superficial and a deep group. The *superficial veins* lie in the subarachnoid space and terminate in the various cranial blood-sinuses. They drain the cerebral cortex and communicate very freely with one another. The *deep veins* drain the substance of the brain and eventually enter the internal cerebral veins or the great cerebral vein (of Galen) (p. 27).

Classification of Sensory Nerves.—Head and Sherren have pointed out that the afferent fibres of cerebro-spinal nerves may be subdivided into three groups :—(*a*) Those which

are concerned in the perception of painful stimuli and in the recognition of extremes of temperature—*protopathic sensibility*; (*b*) those which are concerned in the perception and localisation of light touch and in the recognition of intermediate degrees of temperature—*epicritic sensibility*; (*c*) those which are concerned in muscle and joint sense and in the appreciation of deep touch—*deep sensibility*. The fibres which convey deep sensibility run in the muscular branches and those conveying joint sense are carried to their destination by the tendons.

When a nerve is completely divided proximal to the point at which it gives off its first branch, the area of sensory loss is usually smaller than the area of known anatomical supply, because the areas supplied by adjoining sensory nerves overlap one another to a greater or less extent. This overlapping is more marked in the case of protopathic and deep sensibility than it is in the case of epicritic sensibility. On this account, when a nerve, such as the median, is divided above the origin of its first branch, the epicritic loss is considerably in excess of the loss of protopathic and deep sensibility. The fact that the fibres conveying deep sensibility pass with the motor branches and run along the tendons is of great importance, because it explains why there is no loss of deep sensibility when a nerve is cut distal to the origin of its motor branches. In these cases, a superficial examination may fail to detect the existing sensory loss, and it is, therefore, necessary to examine for epicritic sensibility in all cases of suspected or possible nerve injury. It must also be observed that the division of tendons, with or without the division of a nerve, will usually lead to some impairment of deep sensibility.

THE SPINAL NERVES

Each spinal nerve is formed by the union of an anterior and a posterior nerve-root. The **anterior nerve-roots** are purely motor, and they arise from the large nerve-cells in the anterior column of grey matter in the spinal medulla.

The **posterior nerve-roots** are purely sensory, and they enter the spinal medulla at the apex of the posterior column of grey matter. Each posterior nerve-root has a ganglion upon it containing cells, which send peripheral fibres into the nerve and central fibres into the spinal medulla, where they establish connexions with the higher neurones. The two nerve-roots unite with one another in the intervertebral foramen to form a **spinal nerve,** which divides, almost at once, into **anterior** and **posterior rami (primary divisions)** (Fig. 59).

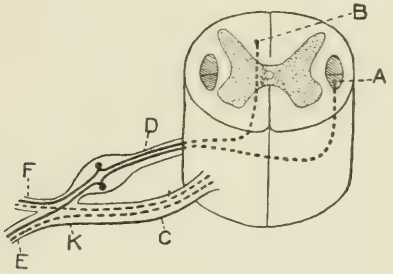


FIG. 59.—Diagram to illustrate the course taken by Sensory Fibres after entering the Spinal Medulla.

A. Spino-thalamic tract (painful, thermal and tactile sensations).
B. Posterior funiculus of spinal medulla (muscle and joint sense, and a few tactile fibres).
C. Anterior nerve-root.
D. Posterior nerve-root
E. Anterior ramus (primary division).
F. Posterior ramus.
K. Typical spinal nerve.

As the spinal medulla is much shorter than the vertebral canal, in which it lies, the nerve-roots in the cervical region are much shorter than those in the thoracic and other regions, and the lower part of the canal is occupied by the long nerve-roots of the lower lumbar, the sacral and the coccygeal nerves.

Both of the rami into which each spinal nerve divides are mixed nerves. The posterior rami (primary divisions) are entirely distributed to the muscles and skin of the back of the trunk, neck and head. The anterior rami form the cervical,

brachial, lumbar, sacral and pudendal plexuses, while, in the thoracic region, they constitute the intercostal nerves.

The spinal nerves are named according to the region of the vertebral column at which they emerge from the vertebral canal. Thus there are eight cervical, twelve thoracic, five lumbar, five sacral and one coccygeal nerve on each side of the body.

THE POSTERIOR RAMI (PRIMARY DIVISIONS)

Each posterior ramus, typically, divides into lateral and medial branches, of which one is distributed to both skin and muscles, while the other supplies muscles only.

The **First Cervical Nerve** sends no branches to the skin, but the medial branch of the second, termed the **greater occipital nerve**, ascends over the back of the scalp and supplies an extensive cutaneous area. It is usually aided in this distribution by the **third occipital nerve**, which represents the medial branch of the **third cervical nerve**. In the occipito-cervical type of neuralgia, the pain is experienced over the area supplied by the two occipital nerves.

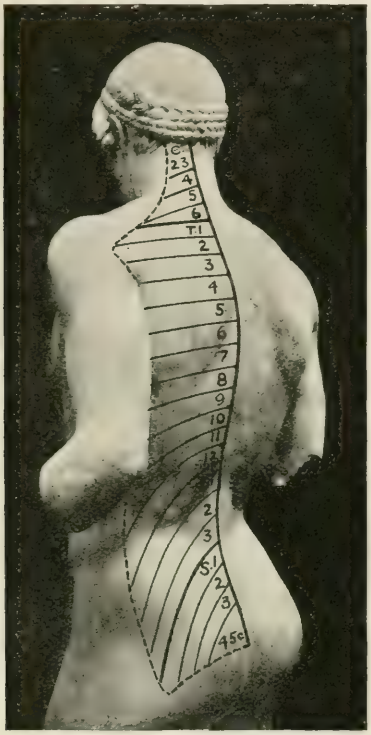
The **fourth, fifth** and **sixth cervical nerves** supply the skin of the back of the neck above the level of the superior border of the scapula, but the **seventh** and **eighth cervical nerves** are distributed solely to muscles (Fig. 60).

The **upper thoracic nerves** supply the extensor muscles of the vertebral column, and their cutaneous branches supply horizontal bands of skin extending from the median plane to the posterior axillary line (Fig. 60). The **lower thoracic nerves** give off corresponding motor branches and their cutaneous branches become increasingly oblique, so that the **twelfth** supplies the skin over the iliac crest.

In the **upper three lumbar nerves**, which have a similar distribution, this obliquity becomes still more marked, and their terminal branches supply the skin of the buttock. The **fourth** and **fifth lumbar nerves** do not reach the skin.

The **upper three sacral nerves** give off branches to the

lower part of the sacra-spinalis (erector spinæ) and cutaneous branches to the buttock. The **fourth** and **fifth sacral nerves**



[*Photo by Alinari.*

FIG. 60.—The Areas of Skin supplied by the Posterior Rami (primary divisions) of the Spinal Nerves.

NOTE.—The posterior rami of C. 1, 7 and 8, and L. 4 and 5, do not supply any branches to the skin.

unite with the **coccygeal**, and the small trunk formed in this way supplies a limited area of skin over the coccyx.

Referred pain from visceral disturbances is usually experienced in the areas of distribution of the anterior rami, but it

may also involve the posterior rami. In cases of gastric ulcer or ureteral calculus, areas of cutaneous hyperalgesia are frequently to be found in the regions supplied by the posterior rami. Sometimes, however, the pain is not referred to the skin, but to the sensory nerve-endings in the muscles of the back, and it then gives rise to areas of muscular hyperalgesia which can readily be recognised, if the finger is carried downwards over the sacro-spinalis (erector spinæ). Gentle pressure is sufficient to make the patient wince in quite a characteristic way when the finger passes over the hyperalgesic area.

THE ANTERIOR RAMI (PRIMARY DIVISIONS)

The anterior rami of the upper four cervical nerves take part in the formation of the **Cervical Plexus**, which is placed under cover of the sterno-mastoid muscle.

The *cutaneous branches* of this plexus supply a large area of skin, extending downwards on the trunk to the level of the second rib (Fig. 61), where the branches of the third and fourth cervical nerves overlap the branches of the second thoracic. The intervening nerves (C. 5–8, T. 1) do not appear on the surface of the trunk, as they are destined for the supply of the upper limb. On this account, the line of anæsthesia on the anterior surface of the body is the same for all fracture-dislocations of the vertebral column occurring between the fourth cervical and the first thoracic vertebræ, and it therefore bears no relation to the site of the injury. The cervical plexus (C. 3 and 4) is responsible for the supply of the skin over the acromion and over the proximal part of the deltoid (*vide infra*).

Of the *motor branches* of the cervical plexus, the **Phrenic Nerve** is the most important. Most of its fibres come from the fourth cervical nerve, but it usually receives a few fibres either from the third or the fifth, in addition. The phrenic nerve descends through the neck, lying behind the internal jugular vein, and comes into intimate relation with the lower

anterior group of the deep cervical lymph glands and the cervical dome of the pleura. It crosses the apical pleura, obliquely, medially and backwards, and gains the mediastinal space (Fig. 122). On the *left side*, the phrenic nerve crosses the

[*Photo by Alinari.*

FIG. 61.—The Nerve-supply of the Anterior Aspect of the Trunk.

arch of the aorta and the left side of the pericardium, before reaching the diaphragm, to which it is distributed. On the *right side*, the nerve descends close to the superior vena cava and then crosses the right side of the pericardium. It not only supplies the right half of the diaphragm but some of its

fibres accompany the inferior vena cava into the abdomen, where they are distributed to the liver substance, the gall bladder and the bile ducts.

As it lies in the root of the neck, the phrenic nerve may become embedded in the deep cervical glands when they are affected with tuberculous disease, or it may be involved by the pleuritic thickening which usually accompanies apical phthisis. Under these circumstances, the contractions of the diaphragm may be incomplete and irregular, a condition not uncommon in phthisis in both its early and its later stages.

The phrenic nerves, like all motor nerves, convey the afferent fibres from the muscles which they supply, and those fibres which the right phrenic supplies to the liver, etc., are also afferent. When the terminal branches of the phrenic are stimulated, the pain may be referred, not to the structure at fault but to the cutaneous distribution of the nerves from which the phrenic takes origin (C. 3, 4 and 5). In tropical abscess of the liver, 16 per cent. of cases are said to experience pain over the right shoulder region (Fig. 61), and the same symptom may be noted, though less commonly, in diaphragmatic pleurisy and cholecystitis (see also p. 190).

The remaining motor branches supply the prevertebral muscles, including the *levator scapulæ* (C. 3 and 4), and assist the accessory nerve to innervate the *sterno-mastoid* (C. 2 and 3) and the *trapezius* (C. 3 and 4).

The upper four cervical nerves are rarely involved in injuries, as they are short and not liable to be stretched and torn. Strains of sufficient violence to injure these nerves will probably produce a fracture-dislocation of the cervical vertebral column.

THE BRACHIAL PLEXUS

The **Brachial Plexus** is formed by the anterior rami of the lower four cervical and the first thoracic nerves, and the manner in which these nerves are connected to one another is very constant.

The fifth and sixth cervical nerves unite to form the **upper trunk**; the seventh cervical nerve constitutes the **middle trunk**, and the eighth cervical and first thoracic nerves unite to form the **lower trunk**. Each trunk divides into an anterior and a posterior division, and the three posterior divisions unite with one another, forming the **posterior cord**. The anterior divisions of the upper and middle trunks unite to form the **lateral cord**, while the anterior division of the lower trunk constitutes the **medial cord.**

Prior to the formation of the cords, certain nerves arise from the plexus. They are termed the **supra-clavicular branches** and they include (1) the supra-scapular nerve, (2) the nerve to the subclavius, (3) the long thoracic nerve (of Bell), and (4) the dorsalis scapulæ nerve (to the rhomboids).

The remaining branches of the brachial plexus arise from the three cords. The **lateral cord** gives off (1) the lateral anterior thoracic nerve, (2) the musculo-cutaneous nerve, and (3) the lateral head of the median nerve.

The **posterior cord** gives off (1) the upper subscapular nerve, (2) the thoraco-dorsal (middle or long subscapular nerve), (3) the lower subscapular nerve, (4) the axillary (circumflex) nerve, and (5) the radial (musculo-spiral) nerve.

The **medial cord** gives off (1) the medial anterior thoracic nerve, (2) the medial cutaneous nerve of the arm (lesser internal cutaneous), (3) the medial cutaneous nerve of the forearm (internal cutaneous), (4) the medial head of the median nerve, and (5) the ulnar nerve.

It is necessary to describe not only the distribution of each individual branch of the plexus but also the destination of the individual spinal nerves which form the plexus, because lesions of the spinal medulla or of the spinal nerves produce effects which may involve several nerves, some of them only partially, whereas lesions of individual branches are necessarily confined to those branches, although affecting the areas supplied by more than one spinal nerve (*vide infra*).

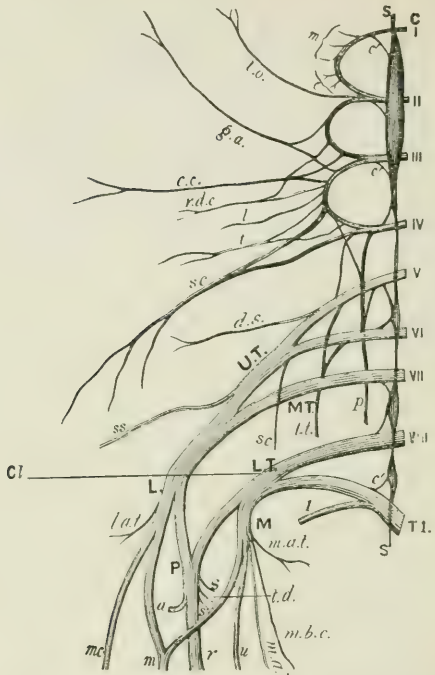


FIG. 62.—Diagram to show the branches and the mode of formation of the Cervical and the Brachial Plexuses. (TURNER'S *Anatomy*.)

Cl. Line of clavicle.
L. Lateral cord.
L.T. Lower trunk.
M. Medial cord.
M.T. Middle trunk.
P. Posterior cord.
S. Sympathetic trunk.
U.T. Upper trunk.
a. Axillary (circumflex) nerve.
c'. Grey ramus communicans.
c.c. Nervus cutaneus colli.
d.s. Dorsalis scapulæ nerve (to rhomboids).
g.a. Great auricular nerve.
l. Nerve to levator scapulæ.
l.o. Lesser occipital nerve.
l.a.t. Lateral anterior thoracic nerve.
l.t. Long thoracic nerve (of Bell).
m. Median nerve.
m.a.c. Medial cutaneous nerve of forearm.
m.b.c. Medial cutaneous nerve of arm.
m.a.t. Medial anterior thoracic nerve.
mc. Musculo-cutaneous nerve.
p. Phrenic nerve.
r. Radial (musculo-spiral) nerve.
r.d.c. Ramus descendens cervicalis.
s. Subscapular nerve.
sc. Supraclavicular nerves.
ss. Suprascapular nerve.
t. Nerve to trapezius.
t.d. Thoraco-dorsal (long subscapular) nerve.
u. Ulnar nerve.

The Supra-clavicular Branches of the Brachial Plexus

1. The **Supra-scapular nerve** (C. 5 and 6) supplies the supra- and the infra-spinatus muscles.

The *supra-spinatus* arises from the supra-spinous fossa of the scapula and runs laterally above the capsule of the shoulder-joint to be inserted into the greater tubercle of the humerus. It initiates the movement of abduction at the shoulder-joint and helps the deltoid to maintain the limb in that position. The bulk of the muscle is hidden by the insertion of the trapezius, but when the supra-spinatus becomes atrophied there is some hollowing out above the spine of the scapula.

The *infra-spinatus* arises from the large infra-spinous fossa of the scapula and runs laterally, posterior to the capsule of the shoulder-joint, to be inserted into the greater tubercle of the humerus. It is a powerful lateral rotator, and it assists in the movements of adduction and extension. The infra-spinatus is partly overlapped by the deltoid, the trapezius and the latissimus dorsi, but, when it is atrophied, the dorsal surface of the scapula can readily be palpated through the skin above the inferior angle, as the muscle is only covered by fasciæ in that situation.

Lesions of the supra-scapular nerve are by no means common. They result in weakening of the movements of abduction and lateral rotation at the shoulder, but as the deltoid and the teres minor are not involved, the disability is not very marked. In many cases the movement of abduction cannot be initiated, but, if passively commenced, it can be continued and maintained. No sensory changes accompany complete paralysis of the supra-scapular nerve.

2. The **Nerve to the Subclavius** (C. 5 and 6) is of little practical importance. The subclavius, which extends from the inferior aspect of the clavicle to the sternal end of the first rib, helps to steady the clavicle during movements at the shoulder-joint. Paralysis of this muscle produces little disability.

3. The **Dorsalis Scapulæ Nerve** (C. 5) arises from the anterior ramus of C. 5 before the latter joins C. 6 to form the upper trunk of the plexus. The nerve crosses the floor of

the posterior triangle of the neck and runs along the vertebral border of the scapula to supply the *rhomboids*, *major and minor*.

These two muscles arise from the spines of the upper thoracic and lower cervical vertebræ, and pass downwards and laterally to be inserted into the vertebral border of the scapula. When they contract, they draw the scapula upwards and medially, thus helping to brace back the shoulders. In paralysis of the rhomboids, the weight of the upper limb draws the scapula downwards and, as the lower part of the serratus anterior is unopposed, the inferior angle is tilted in a lateral direction. The condition is determined by a careful comparison of the relative positions of the two scapulæ.

4. The **Long Thoracic Nerve (of Bell)** arises by three roots, which spring from the fifth, sixth and seventh cervical nerves, before the formation of the trunks of the brachial plexus. It enters the axilla and descends on the medial wall to supply the serratus anterior.

The *Serratus Anterior* arises from the upper eight ribs, a little in front of the mid-axillary line, and its fibres pass backwards, round the chest wall and closely applied to it, to be inserted into the ventral aspect of the vertebral border of the scapula. When the muscle contracts, it draws the scapula forwards and laterally and, at the same time, it rotates it clockwise (as seen from in front).

Movements of flexion and abduction at the shoulder-joint itself are limited to 90°, and, although these movements can apparently be carried out to an angle of about 160°, the additional range is obtained by movements of the shoulder-girdle as a whole. This additional movement is produced mainly by the serratus anterior and the trapezius.

The serratus anterior plays an important part in forward pushing movements, but it is aided by the trapezius and the rhomboids, which help to steady the scapula. When the long thoracic nerve is injured alone, the patient cannot flex his arm beyond a right angle, and if the arm is passively

flexed beyond that angle, the patient is unable to perform any forward pushing movements. Under these conditions, his endeavours result in marked "*winging*" *of the scapula.* On the other hand, forward pushing movements with the arm flexed to less than a right angle are not only possible, but they do not produce any "winging" of the scapula, which is steadied by the trapezius and the rhomboids (Sherren).

If, however, either or both of the latter muscles are paralysed in addition to the serratus anterior, forward pushing movements carried out in any plane cause "winging" of the scapula. The combined lesion appears to be the less uncommon condition.

When the scapula is fixed by the contraction of the trapezius and the rhomboids, the serratus anterior can help inspiration by elevating the upper eight ribs. Patients suffering from chronic bronchitis and emphysema bring into use all the auxiliary muscles of respiration when they are seized by a fit of coughing, and the digitations of the serratus anterior stand out in relief on the medial wall of the axilla, more especially in spare subjects.

The Infra-clavicular Branches of the Brachial Plexus

(A) **Lateral Cord.**—The **Lateral Anterior Thoracic Nerve** (C. 5, 6 and 7) supplies the whole of the clavicular head and part of the costo-sternal head of the pectoralis major.

The *pectoralis major* covers the upper part of the anterior chest wall, and its lower border constitutes the anterior axillary fold. In the female, it is partly obscured by the mammary gland. From its origin the muscle passes laterally to be inserted into the proximal part of the humerus. Its line of pull lies below and anterior to the centre of the shoulder-joint, and the muscle therefore acts as a flexor, adductor and medial rotator of the arm.

Paralysis of the pectoralis major occurs along with paralysis of other muscles in injuries of the upper trunk of the brachial

plexus and in lesions of the spinal medulla, etc., but as an isolated condition it is practically unknown.

The costo-sternal head may be removed in the complete operation for scirrhus mammæ or it may be absent congenitally without causing any noticeable disability. When this part of the muscle is absent congenitally, there is visible deformity and the chest appears to be much flatter on the affected side. The condition, however, does not necessarily predispose to phthisis, and the patient may have an otherwise normal and healthy chest.

The **Musculo-cutaneous Nerve** (C. 5, 6 and 7) contains both motor and sensory fibres. Its motor branches supply the coraco-brachialis, the biceps and the brachialis (b. anticus) muscles.

The *Coraco-brachialis* can be seen and felt on the lateral wall of the axilla, when the arm is fully abducted. It arises from the tip of the coracoid process and is inserted into the middle of the medial aspect of the shaft of the humerus. Its line of pull lies anterior and a little medial to the centre of the shoulder-joint, and the muscle therefore acts as a flexor, adductor and medial rotator of the arm.

The *Biceps* arises from the tip of the coracoid process and from the upper border of the glenoid cavity. As it passes to be inserted into the radial tuberosity, it forms a well-marked elevation on the front of the arm. The biceps is a powerful flexor and supinator of the forearm and it also acts as a weak flexor of the shoulder-joint.

The *Brachialis* lies behind the lower part of the biceps. It arises from the anterior aspect of the humerus and is inserted into the coronoid process of the ulna. It is a powerful flexor of the elbow-joint, but it does not depend for its nerve-supply on the musculo-cutaneous nerve alone, as it also receives a branch from the radial (musculo-spiral) nerve.

The motor symptoms in paralysis of the musculo-cutaneous nerve are great weakness in the movement of flexion at the elbow and impairment in the power of supination, which is normally a much stronger movement than pronation.

The sensory part of the musculo-cutaneous nerve constitutes the **lateral cutaneous nerve of the forearm**. It divides into *volar* (*anterior*) and *dorsal branches*, which supply the corresponding surfaces of the lateral aspect of the

forearm, from the elbow to the wrist. These two branches overlap one another to such an extent that section of one of them alone produces no discoverable alteration in the

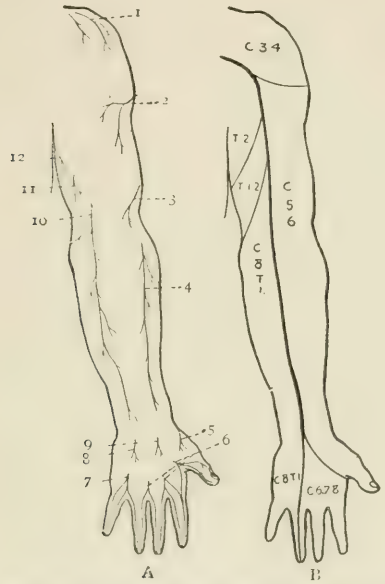


FIG. 63.—The Nerve-supply of the Skin on the Anterior Aspect of the Upper Limb.

A. The individual nerves of supply.
B. The segmental supply.

1. Posterior supraclavicular nerves.
2. Lateral cutaneous nerve of arm.
3. Dorsal cutaneous nerve of forearm.
4. Lateral cutaneous nerve of forearm.
5. Palmar branch of radial nerve.
6. Digital branches of median nerve.
7. Digital branches of ulnar nerve.
8. Palmar branch of ulnar nerve.
9. Palmar branch of median nerve.
10. Medial cutaneous nerve of forearm.
11. Medial cutaneous nerve of arm.
12. Intercosto-brachial nerve.

sensibility of the limb. Further, the dorsal branch overlaps the dorsal cutaneous nerve of the forearm (lower external cutaneous branch of the musculo-spiral nerve), but the volar branch does not overlap the volar branch of the medial

cutaneous nerve of the forearm to any extent. As a result, when the whole of the musculo-cutaneous nerve is paralysed, the sensory disturbance is very ill-defined on the back of the forearm, whereas, on the front of the forearm, a fairly sharp line of demarcation can always be found.

The **lateral head of the median** will be considered along with the medial head (p. 149).

(B) **The Posterior Cord** (C. 5, 6, 7, 8 and T. 1)—The **Upper Subscapular Nerve** (C. 5 and 6) is entirely distributed to the subscapularis, which forms the proximal part of the posterior wall of the axilla.

The *subscapularis* arises from the ventral surface of the scapula, crosses the anterior aspect of the capsule of the shoulder-joint, and is inserted into the lesser tubercle of the humerus. It acts as a medial rotator and assists in flexion and adduction of the humerus. Section of the upper subscapular nerve produces little motor disability, but, as the muscle atrophies, the anterior aspect of the capsule of the shoulder-joint becomes seriously weakened, and this condition predisposes to dislocation.

The **Lower Subscapular Nerve** supplies a few twigs to the subscapularis, but is mainly distributed to the *teres major*. This muscle arises from the dorsal aspect of the inferior angle of the scapula and passes upwards and laterally on the posterior wall of the axilla to be inserted into the floor of the intertubercular sulcus (bicipital groove). It acts as a medial rotator, adductor and extensor of the humerus. Section of the lower subscapular nerve produces no discoverable disability, as the latissimus dorsi has a precisely similar action to that of the teres major.

The **Thoraco-dorsal** (**Long Subscapular**) **Nerve** supplies the *latissimus dorsi* muscle, which is mainly responsible for the formation of the posterior axillary fold. This muscle has a wide origin in the lower part of the back, and it narrows as it passes to its insertion into the medial lip of the intertubercular sulcus (bicipital groove). When both the thoraco-dorsal and the lower subscapular nerves are paralysed, the movement of extension at the shoulder-joint is extremely weak, as it is then performed almost entirely by the posterior fibres of the deltoid, since the infra-spinatus and the teres minor do not act at good mechanical advantage. The posterior fold of the

axilla loses its bulk as the muscles atrophy, and the axillary border of the scapula can then be palpated without difficulty.

The **Axillary (Circumflex) Nerve** arises from the posterior cord in the axilla, where it lies behind the third part of the axillary artery. After passing through the quadrilateral space, it winds round the posterior aspect of the surgical neck of the humerus and so reaches the deep surface of the deltoid. It contains both motor and sensory fibres. The former are distributed to the deltoid and the teres minor.

The *Deltoid* arises from the anterior border of the lateral third of the clavicle, the tip and lateral border of the acromion and the lower border of the spine of the scapula. From this wide origin the fibres pass distally and converge to be inserted into the middle of the lateral surface of the shaft of the humerus. The anterior fibres aid in the movements of flexion and medial rotation, while the posterior fibres take part in the opposite movements. Acting as a whole, the deltoid is a powerful abductor of the humerus, and, in this movement, it is aided only by the supra-spinatus (p. 131).

The *teres minor* lies along the lateral border of the infra-spinatus, and it performs the same actions as that muscle, *i.e.* it laterally rotates, adducts and extends the humerus.

When the axillary nerve is paralysed, abduction of the humerus is the only movement which is markedly affected. A certain degree of this movement, however, is still possible, as the supra-spinatus is not involved, and, further, the latter muscle is assisted by the serratus anterior, which acts through the shoulder-girdle. Atrophy of the deltoid is easy to determine. The deltoid covers the greater tubercle of the humerus and, in this way, it gives the shoulder its normal rounded appearance. In atrophy of the muscle, the lateral border of the acromion becomes more distinct and the shoulder loses its normal contour. The tubercles are easy to palpate and the coracoid process, which is normally covered by the anterior fibres of the muscle, may cause a surface elevation below the junction of the intermediate and lateral thirds of the clavicle.

The *cutaneous branches* of the axillary nerve supply the skin over the distal two-thirds of the deltoid. They are slightly overlapped, proximally by the posterior supra-clavicular (supra-acromial) nerves (C. 3 and 4) and distally by the dorsal cutaneous branch of the radial nerve (upper external cutaneous branch of the musculo-spiral nerve) (Fig. 63). In complete paralysis of the axillary nerve, the skin over the distal two-thirds of the deltoid shows loss of both epicritic and protopathic sensibility. The combination of the motor and sensory phenomena renders paralysis of this nerve easy to determine.

The **Radial (Musculo-spiral) Nerve** arises from the posterior cord in the axilla and descends behind the artery. In this part of its course it lies medial to the proximal part of the shaft of the humerus, against which it is compressed in "crutch" and "Saturday night" paralyses. A short distance beyond the posterior fold of the axilla, it passes distally and laterally across the posterior aspect of the humerus in the radial groove. At the distal extremity of the groove, the nerve re-enters the anterior compartment of the arm and, in front of the lateral epicondyle of the humerus, it ends by dividing into *superficial* and *deep branches* (O.T. *radial* and *posterior interosseous nerves*).

The radial nerve can be rolled against the lateral aspect of the humerus as it pierces the lateral intermuscular septum. This point corresponds to the junction of the middle and proximal thirds of the line joining the insertion of the deltoid to the tip of the lateral epicondyle. Proximal to that point, the radial nerve may be rolled against the floor of the radial groove on deep pressure through the triceps.

As the radial (musculo-spiral) nerve passes through the axilla, it gives off a cutaneous branch, which supplies the skin on the dorsum of the arm (Fig. 64), and motor branches to the long and medial heads of the triceps. In the radial groove, the nerve supplies branches to all three heads of the triceps and to the anconæus. At the distal extremity of the groove it gives off the **dorsal cutaneous nerve of the forearm.** This branch breaks up into *proximal* and *distal* divisions (upper and lower

external cutaneous branches of musculo-spiral), which supply the antero-lateral aspect of the arm and the middle part of the

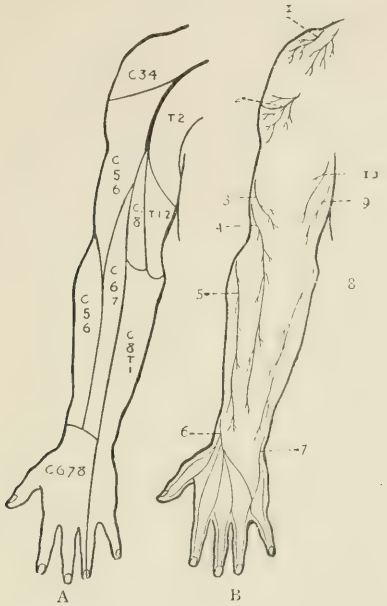


FIG. 64.—The Nerve-supply of the Skin on the Dorsal Aspect of the Upper Limb.

A. The segmental supply.
B. The individual nerves of supply.

1. Posterior supra-clavicular nerves.
2. Lateral cutaneous nerve of arm.
3, 4. Dorsal cutaneous nerve of forearm (upper and lower external cutaneous branches of musculo-spiral nerve).
5. Lateral cutaneous nerve of forearm.
6. Superficial division of radial nerve.
7. Dorsal cutaneous branch of ulnar nerve.
8. Medial cutaneous nerve of forearm (internal cutaneous nerve).
9. Intercosto-brachial nerve.
10. Posterior cutaneous nerve of arm (internal cutaneous branch of musculo-spiral nerve).

dorsum of the forearm, respectively (Fig. 64). After piercing the lateral intermuscular septum and re-entering the anterior compartment of the arm, the radial (musculo-spiral) nerve sends

branches to the brachio-radialis (supinator longus), the extensor carpi radialis longus and the brachialis (p. 134).

The *Triceps* arises by three heads. The *long head* arises from the upper part of the axillary border of the scapula and it can be palpated distal to the posterior fold of the axilla, when the forearm is actively extended. The *lateral* and *medial heads* arise from the posterior aspect of the humerus. When the lateral head contracts, it forms an oblique ridge on the back of the arm, just below the posterior border of the deltoid.

The triceps is inserted into the proximal surface of the olecranon, and acts as a powerful extensor of the elbow. In this action it is aided by the anconæus, a small muscle which passes from the posterior aspect of the lateral epicondyle of the humerus to the lateral aspect of the olecranon.

The *Brachio-radialis* is an extremely important muscle in many ways. It arises from the lateral intermuscular septum and the lateral epicondylic ridge of the humerus, and is inserted into the lateral aspect of the radius, just proximal to the styloid process. *Its principal action is flexion of the elbow, and when that movement is attempted against resistance, the brachio-radialis forms an unmistakable prominence on the lateral part of the front of the forearm.* When the limb is supine, the line of the pull of the brachio-radialis lies medial to the axis of the movement of pronation, and therefore the muscle acts as a pronator, in the initial stage of pronation. But, in the mid-prone position, the line of pull exactly overlies the axis of movement and the muscle ceases to act as a pronator. When the limb is fully pronated, the line of pull lies lateral to the axis of movement, and the brachio-radialis, therefore, may act as a supinator until the mid-prone position is reached.

The brachio-radialis is paralysed when the radial (musculo-spiral) nerve is injured in the radial groove or in the axilla, but it is not affected in the "wrist-drop" paralysis of lead-poisoning.

The *Extensor Carpi Radialis Longus* lies under cover of the brachio-radialis. It arises from the humerus and the lateral intermuscular septum just distal to that muscle and is inserted into the dorsum of the base of the second metacarpal bone. It is a powerful extensor of the wrist-joint and, when the forearm is pronated, it assists in flexion of the elbow-joint. *Like the brachio-radialis, it commonly escapes in lead-poisoning, but as the other carpal extensors are involved its action may be masked by the tonus of the carpal flexors when an endeavour is made to extend the wrist. If, however, the hand is supported during the movement, the contraction of the extensor carpi radialis longus can be satisfactorily demonstrated.*

The actions and attachments of the *Brachialis* are described on page 134.

The **Deep Branch of the Radial Nerve** supplies the *supin-*

ator (*brevis*) and is thereafter termed the **Dorsal Interosseous Nerve.** It winds round the proximal part of the radius and gains the posterior compartment of the forearm. It supplies all the extensor muscles of the fingers and wrist, except the extensor carpi radialis longus.

When the dorsal aspect of the forearm is examined, a distinct longitudinal groove is seen slightly to the ulnar side of the middle line. When this groove is palpated, it is found to correspond to the subcutaneous dorsal border of the ulna. The extensor muscles lie to the radial side of the groove, and the mass which lies to its ulnar side is formed by the flexor digitorum profundus and the flexor carpi ulnaris.

The group of muscles supplied by the dorsal interosseous nerve includes the *extensor carpi radialis brevis*, *the extensor carpi ulnaris*, *the extensor digitorum communis*, *the extensor digiti quinti proprius*, *the extensor indicis proprius*, *the abductor pollicis longus*, *the extensor pollicis longus and brevis.*

The **Superficial Branch of the Radial Nerve** (O.T. Radial) is purely sensory. It supplies branches to the skin (1) of the thenar eminence, (2) of the radial part of the dorsum of the hand, (3) of the dorsal aspects of the lateral three and a half digits, except over the distal and part of the middle phalanx. It must be remembered that this nerve establishes connexions with (1) the lateral cutaneous nerve of the forearm (p. 134), (2) the dorsal cutaneous nerve of the forearm (p. 138) and (3) the dorsal branch of the ulnar nerve. On this account, division of the superficial branch of the radial nerve produces no appreciable alteration in the sensibility of the skin areas which it supplies (Sherren).

Radial (Musculo-spiral) Paralysis.—Complete division of the radial nerve before any of its branches are given off results in widespread motor paralysis, but the sensory loss is relatively insignificant. The triceps and anconæus are paralysed, and, therefore, active extension of the elbow is impossible and the joint is maintained in a semi-flexed attitude by the tonus of the flexors of the forearm. The paralysis of the brachio-

radialis does not produce any special attitude, but, as all the extensors of the wrist and fingers are involved, the wrist and fingers are maintained in a position of flexion by the tonus of their flexor muscles. At the same time, it should be remembered that the lumbricals and interossei (p. 145) are able to extend the interphalangeal joints of the medial four digits, and care must be taken not to assume that such a movement, occurring during an endeavour to extend the fingers and wrist, is produced by the extensor muscles.

When the radial (musculo-spiral) nerve is divided *distal to the point of origin of the dorsal cutaneous nerve of the forearm*, there is no appreciable loss of sensibility in the forearm or hand, on account of the communications which exist between the superficial branch and the adjoining nerves (p. 141). If the radial nerve is divided *proximal to the point of origin of the dorsal cutaneous nerve of the forearm*, the sensory loss involves the radial side of the dorsum of the hand. The forearm is not affected, owing to the overlapping of the dorsal cutaneous nerve by the lateral and medial cutaneous nerves of the forearm. · Both epicritic and protopathic sensibilities are lost over the radial half of the dorsum of the hand and over the dorsal aspect of the first phalanx of the thumb, but, owing to overlapping by the volar (palmar) digital nerves, the second, third and fourth digits are not affected.

The superficial branch of the radial nerve establishes its communications in the distal third of the forearm, and, when it is injured in this part of its course, some loss of sensibility may be discovered on the dorsum of the hand.

(C) **The Medial Cord** (C. 8 and T. 1).—The **Medial Anterior Thoracic Nerve** supplies the pectoralis minor and assists the lateral anterior thoracic nerve to supply the pectoralis major (p. 133).

The pectoralis minor lies under cover of the major and extends from the sternal ends of the third, fourth and fifth ribs to the coracoid process of the scapula. When it contracts, it draws the point of the shoulder downwards and forwards; or,

if the scapula is fixed, it can act as an auxiliary muscle of respiration. It is never paralysed alone.

The **Medial Cutaneous Nerve of the Arm (Lesser Internal**

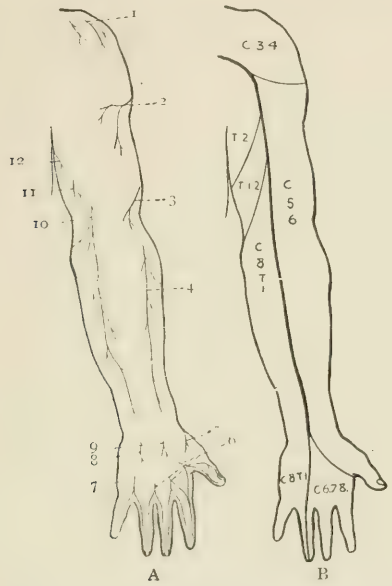


FIG. 65.—The Nerve-supply of the Skin on the Anterior Aspect of the Upper Limb.

A. The individual nerves of supply.
B. The segmental supply.

1. Posterior supraclavicular nerves.
2. Lateral cutaneous nerve of arm.
3. Dorsal cutaneous nerve of forearm.
4. Lateral cutaneous nerve of forearm.
5. Palmar branch of radial nerve.
6. Digital branches of median nerve.
7. Digital branches of ulnar nerve.
8. Palmar branch of ulnar nerve.
9. Palmar branch of median nerve.
10. Medial cutaneous nerve of forearm.
11. Medial cutaneous nerve of arm.
12. Intercosto-brachial nerve.

Cutaneous) communicates with the intercosto-brachial (intercosto-humeral, T. 2) and then supplies the skin on the dorso-medial aspect of the arm. In angina pectoris (p. 192) and, sometimes, in malignant disease of the breast referred pain is

experienced in the area supplied by this nerve. In the latter case, the condition may be caused by direct pressure on the nerve by enlarged lymph glands in the axilla.

The **Medial Cutaneous Nerve of the Forearm (Internal Cutaneous)** (C. 8 and T. 1) pierces the deep fascia about half-way down the arm, and divides into volár (anterior) and ulnar (posterior) branches. These two branches are responsible for the supply of the skin over the medial half of the forearm, and, although they overlap one another with great freedom, they do not overlap the adjoining nerves to the same extent. As a result, when either branch is divided alone, the sensory loss is sharply demarcated on the radial side, but it disappears very gradually on the ulnar side. The area supplied by this nerve may be involved in the referred pain of angina pectoris (p. 192).

The **Ulnar Nerve** (C. 8 and T 1) arises from the medial cord of the plexus in the axilla, and is placed on the medial side of the brachial artery in the proximal part of the arm. In the distal part of the arm it leaves the anterior compartment and passes behind the medial epicondyle of the humerus. In this situation the nerve is only covered by skin and fasciæ, and, as it is in direct contact with the bone, it is consequently exposed to injury.

At the elbow, the ulnar nerve supplies branches to the flexor carpi ulnaris and to the part of the flexor digitorum profundus which acts on the ring and little fingers.

Its course through the forearm corresponds to a line drawn from the medial epicondyle to the lateral side of the pisiform bone, which can easily be felt on the ulnar side of the wrist at the proximal border of the hypothenar eminence. Proximally it is covered by the fleshy belly of the flexor carpi ulnaris, but near the wrist it becomes superficial and lies on the lateral side of the tendon of that muscle.

The *Flexor Carpi Ulnaris* arises both from the medial epicondyle and from the medial side of the olecranon. It descends on the ulnar side of the forearm, and its tendon can be traced to its insertion into the pisiform

bone. Under ordinary conditions, the muscle acts along with the other flexors of the wrist, but, when it contracts alone, it produces ulnar deviation of the hand in addition to flexion of the wrist. Ulnar deviation of the hand, without either flexion or extension, is produced by the simultaneous contraction of the flexor carpi ulnaris and the extensor carpi ulnaris. Inability to carry out this movement must indicate paralysis or paræsis of one or other of these muscles.

In the *distal part of the forearm* the ulnar nerve gives off a *volar* (*palmar*) *cutaneous branch*, which supplies the skin over the hypothenar eminence, and a *dorsal cutaneous branch*, which supplies the ulnar side of the dorsum of the hand and the proximal parts of the dorsal aspects of the little finger and the ulnar side of the ring finger.

In the *hand*, the ulnar nerve terminates by dividing into superficial and deep branches. The *superficial branch* supplies the skin on the volar aspect of the little finger and the ulnar side of the ring finger. In addition, it supplies the distal parts of the dorsal aspects of the same two digits.

The **Deep Branch of the Ulnar Nerve** gives off no cutaneous branches, but it supplies the muscles of the hypothenar eminence, all the interossei, the medial two lumbricals and the adductor pollicis.

The muscles which constitute the *hypothenar eminence* comprise the *abductor*, the *opponens* and the *flexor brevis digiti quinti*. The actions of these muscles are indicated by their names, but, under normal conditions, the little finger possesses little power of opposition, as the ligaments of the joint between the fifth metacarpal bone and the hamate (unciform) bone allow very little rotatory movement.

Atrophy of this group of muscles is easily recognised. It occurs in lesions (1) of the ulnar nerve, (2) of the lower trunk of the brachial plexus, *e.g.* Klumpke's paralysis, or following pressure by a cervical rib, and (3) of the lower part of the cervical enlargement of the spinal medulla, *e.g.* progressive muscular atrophy.

The *Lumbricals* are four small muscles which arise from the

tendons of the flexor digitorum profundus. They are inserted into the radial side of the base of the proximal phalanx of each of the medial four digits. In addition, their tendons are attached to the expansion of the extensor tendons, which covers the dorsal aspect of the proximal phalanx. By virtue of their bony insertions, these muscles act as flexors of the metacarpo-phalangeal joints, but by virtue of their connexion with the extensor expansion they extend the two interphalangeal joints at the same time (*vide infra*). The lumbricals for the little and ring fingers are supplied by the deep branch of the ulnar

FIG. 66.—Tendons attached to a Finger. (TURNER'S *Anatomy*.)

a. Extensor digitorum communis.
b. Flexor digitorum profundus.
c. Flexor digitorum sublimis.
d. Lumbrical muscle.
e. Dorsal interosseous muscle.
f. Dorsal expansion of extensor tendon.

nerve, but the lateral two lumbricals are innervated by the median (p. 152).

The *Volar* (*Palmar*) *Interossei* are three in number, and they act on the index, ring and little fingers. Each arises from the volar aspect of the metacarpal bone of the finger on which it acts, and each is inserted into the dorsum of the base of the proximal phalanx and the extensor expansion. The volar interossei for the ring and little fingers are inserted on the radial sides of their respective phalanges, but that for the index finger is inserted on the ulnar side.

When the volar interossei contract, they adduct the index, ring and little fingers to the middle finger. In addition, they flex the metacarpo-phalangeal joints, while extending the inter-phalangeal joints (cf. Lumbricals).

The *Dorsal Interossei* act as abductors of the index, middle and ring fingers. The first dorsal interosseous arises from the adjacent sides of the first and second metacarpal bones, and is inserted into the radial side of the dorsum of the base of the proximal phalanx of the index finger. When the thumb is adducted, the first dorsal interosseous muscle produces a swelling on the dorsum of the hand between the first and second metacarpal bones, and it can be felt to contract during abduction of the index. Atrophy of this muscle occurs at an early stage in progressive muscular atrophy.

The second and third dorsal interossei occupy the spaces between the second and third, and third and fourth metacarpal bones, respectively. The former is inserted into the radial side and the latter into the ulnar side of the first phalanx of the middle finger. They abduct the middle finger to the radial and ulnar sides respectively.

The fourth dorsal interosseous muscle occupies the space between the fourth and fifth metacarpal bones, and is inserted into the ulnar side of the dorsum of the base of the proximal phalanx of the ring finger.

When the dorsal interossei become atrophied, hollows appear on the dorsum of the hand between the metacarpal bones, and the latter can not only be palpated but may even be gripped between the examining finger and thumb.

The *Adductor Pollicis* possesses a wide origin from the volar aspect of the carpus and the third metacarpal bone, and it is inserted into the ulnar side of the base of the proximal phalanx of the thumb. In studying the movement of adduction of the thumb, it must be remembered that the first metacarpal bone is so placed that what is usually described as its dorsal surface is, in reality, directed laterally, when the supine hand is by the side. Adduction of the thumb brings the ulnar border of the first metacarpal towards the radial side of the second metacarpal, and the movement occurs in an antero-posterior plane, provided that the hand is supine and by the side, as in the erect attitude. Abduction

of the thumb, which is the reverse movement, must also occur in this plane (see also p. 151).

When the ulnar nerve is divided near the wrist, all the intrinsic muscles of the hand are paralysed, with the exception of those supplied by the median nerve (p. 151). Owing to the paralysis of the interossei, the movements of abduction and adduction of the fingers are lost, but not necessarily entirely so as their actions may be simulated by the extensor digitorum communis, which, however, can only act when the fingers are extended. At the same time it must be remembered that, mainly owing to the arrangement of the collateral ligaments of the metacarpo-phalangeal joints, free abduction and adduction of the fingers can only be carried out when the joints are in a position of extension. Abduction of the little finger and adduction of the thumb are impossible, although the latter movement may be simulated by the flexor pollicis longus and brevis.

The fingers adopt a *characteristic attitude.* Owing to the paralysis of their interossei, the index and middle fingers are extended at the metacarpo-phalangeal joints and the ring and little fingers adopt a greater degree of the same attitude, as their lumbrical muscles are also paralysed. Hyperextension of the ring and little fingers at the metacarpo-phalangeal joints stretches the tendons of the flexor digitorum sublimis and profundus, which contract and flex the interphalangeal joints. The degree of flexion present in the interphalangeal joints of the index and middle fingers is much less, as their lumbrical muscles are able to oppose the action.

The *sensory loss* depends on the site of the injury. If it occurs *proximal to the origin of the dorsal cutaneous branch,* the sensory loss involves the ulnar halves of both dorsal and volar aspects of the hand, the whole of the little finger and the ulnar half of the ring finger. Unless the injury which divided the nerve has also divided some of the tendons, there is no loss of sensibility to deep pressure. Epicritic sensibility is lost over the whole of the area indicated, but the area of protopathic loss is much smaller (see p. 121).

When the ulnar nerve is injured *distal to the origin of its dorsal cutaneous branch*, only the distal phalanges of the little and ring fingers are affected on the dorsal aspect of the hand. On the volar aspect, the loss of epicritic sensibility is the same as in the former case, but protopathic loss only affects the little finger.

When the ulnar nerve is injured at or proximal to the elbow, the motor symptoms which have already been described are increased by the paralysis of the flexor carpi ulnaris and the ulnar half of the flexor digitorum profundus. As a result, flexion of the wrist is weakened and, when that movement is actively performed, the hand becomes deviated to the radial side. It might appear as if paralysis of the ulnar portion of the flexor digitorum profundus would result in hyperextension of the distal interphalangeal joints, but, as there is only one extensor muscle for all the joints of the fingers, the distal joints cannot be extended when the proximal interphalangeal joints are flexed. The attitude of the fingers, therefore, is not altered by the additional paralysis, and the characteristic *main en griffe* is present, as in the case of injury to the nerve proximal to the wrist.

The *sensory loss* is very similar to that found when the ulnar nerve is divided proximal to the point of origin of its dorsal cutaneous branch, with the important difference that deep sensibility is lost over an area, which corresponds more or less accurately to the area of protopathic loss.

The **Median Nerve** (C. 5, 6, 7, 8 and T. 1) is formed in the axilla by the union of a lateral head, derived from the lateral cord, with a medial head, derived from the medial cord. In the axilla and the arm, the median nerve is closely related to the great vessels and it gives off no branches until it supplies the superficial group of muscles of the forearm. These branches arise just proximal to the elbow and they are distributed to the pronator teres, the flexor carpi radialis, the palmaris longus and the flexor digitorum sublimis.

All these muscles arise from a common origin on the medial epicondyle of the humerus. The *Pronator Teres* passes distally and laterally to be inserted into the middle of the lateral aspect of the radius. It acts as a powerful pronator and as a weak flexor of the forearm. It can be recognised since it forms the medial boundary of the depression which appears in front of the elbow, when the pronated forearm is flexed against resistance.

The *Flexor Carpi Radialis* passes somewhat obliquely through the forearm and is inserted into the bases of the second and third metacarpal bones. Its tendon is rendered prominent just proximal to the wrist, when the joint is actively flexed; it lies about half an inch to the lateral side of the middle line. This muscle bears the same relation to radial deviation of the hand as the flexor carpi ulnaris bears to ulnar deviation (p. 145).

The *Palmaris Longus* is absent in about 10 per cent. of subjects. It is inserted into the palmar aponeurosis, and its tendon can be distinguished to the medial side of the flexor carpi radialis tendon, when the wrist-joint is actively flexed.

The *Flexor Digitorum Sublimis* is partly overlapped by the three preceding muscles. It breaks up into four tendons, which are inserted into the second phalanges of the medial four digits. When the fist is tightly clenched, with the wrist extended, a slight hollow appears on the medial side of the palmaris longus tendon, and in the floor of this depression the tendons for the ring and little fingers can be felt.

The median nerve passes distally through the forearm, deep to the superficial group of muscles. Just distal to the elbow-joint, it gives off the **volar interosseous nerve**, which descends on the interosseous membrane and supplies the deep muscles of the front of the forearm, namely, the flexor pollicis longus, the pronator quadratus and the radial half of the flexor digitorum profundus.

The *Flexor Pollicis Longus* arises from the anterior aspect of the radius and is inserted into the distal phalanx of the thumb. Its tendon is overlapped by the tendon of the flexor carpi radialis and is consequently difficult to feel, but, if the fist is tightly clenched, a visible depression appears on the radial side of the flexor carpi radialis tendon when the flexor pollicis longus is contracted.

The *Pronator Quadratus* arises from the distal part of the volar surface of the ulna and is inserted into a corresponding area on the radius. It is very deeply placed and its contractions cannot be appreciated either by inspection or by palpation.

The *Flexor Digitorum Profundus* arises from the volar aspects of the ulna and interosseous membrane. Near the wrist it breaks up into four tendons which are inserted into the distal phalanges of the medial four fingers. That part of the muscle which is destined for the ring and little fingers is supplied by the ulnar nerve, while the remainder is supplied by the volar interosseous.

In the distal part of the forearm, the median nerve gives off a *volar cutaneous branch*, which supplies the skin over the central part of the palm of the hand. Near the wrist, the nerve becomes more superficial and lies behind the palmaris longus tendon. Neuromata or neuro-fibromata are frequently found on the median nerve in this part of its course.

As it enters the palm of the hand, the median nerve divides into a *lateral* and a *medial* division. The former supplies the skin on the volar aspect of the thumb and the radial half of the volar aspect of the index finger, by means of *digital branches*. These nerves are not restricted to the volar aspects of the index finger and thumb, and they also supply the distal halves of the dorsal aspects of both.

In addition to its digital branches, the lateral division of the median nerve gives off branches to supply the muscles of the thenar eminence, which is formed by the abductor pollicis brevis, the opponens pollicis and the flexor pollicis brevis.

The *Abductor Pollicis Brevis* forms the lateral part of the thenar eminence. It arises from the carpus and is inserted into the radial side of the base of the proximal phalanx of the thumb. In cases where injury of the median nerve near the wrist is suspected, the action of this muscle must be carefully tested. Abduction of the thumb carries it forwards from the palm in an antero-posterior plane (p. 147), and it must be distinguished from extension, which carries the thumb away from the hand in a lateral direction. Pure abduction of the thumb is impossible when the abductor pollicis brevis is paralysed, because the abductor longus (extensor ossis metacarpi pollicis) is really an extensor muscle.

The *Flexor Pollicis Brevis* forms the medial part of the thenar eminence, while the *Opponens Pollicis* lies under cover of both the flexor and the abductor. The latter muscle arises from the radial side of the volar aspect of the carpus and is inserted into the radial border of the first metacarpal bone. When it contracts, it produces a slight amount of medial rotation

of the first metacarpal at the carpo-metacarpal joint, and this rotation, combined with flexion, enables the thumb to be opposed to the little finger.

The muscles of the thenar eminence are usually the first to be involved in progressive muscular atrophy, and they are affected with great constancy in those cases of cervical rib which give rise to symptoms (see also p. 156).

The digital nerve to the radial side of the index finger gives a branch of supply to the first lumbrical muscle (p. 145).

The *medial* division of the median nerve breaks up into two branches, which pass to the clefts between the index and middle, and middle and ring fingers, respectively. The former supplies the second lumbrical muscle. At the cleft, each breaks up into digital nerves for the volar aspects of the adjacent borders of the two fingers. These digital nerves also supply the distal part of the dorsal surface of the fingers (cf. Ulnar Nerve, p. 145).

Injuries of the median nerve may be divided into two groups:—(*a*) Those occurring distal to the origin of the motor branches to the flexor muscles of the forearm but proximal to the origin of the motor branches to the muscles of the thenar eminence. (*b*) Those occurring proximal to the origin of the motor branches to the flexor muscles of the forearm.

(*a*) **When the median nerve is divided near the wrist,** the motor symptoms are not very striking. True abduction and true opposition of the thumb are impossible, but these movements are simulated by the abductor pollicis longus (extensor ossis metacarpi pollicis) and the extensors, and the flexor pollicis longus, respectively. Examination reveals the fact that the abduction obtained does not take place in an antero-posterior plane (p. 151), while in the simulated opposition the metacarpal bone of the thumb is not rotated.

The paralysis of the first and second lumbricals upsets the muscular balance of the hand, and the grasping power is much less than might have been expected. The index and middle fingers tend to be extended at the metacarpo-phalangeal and

flexed at the interphalangeal joints, when the hand is at rest, but these fingers retain all their normal movements.

The *sensory symptoms* are due to the paralysis of the volar

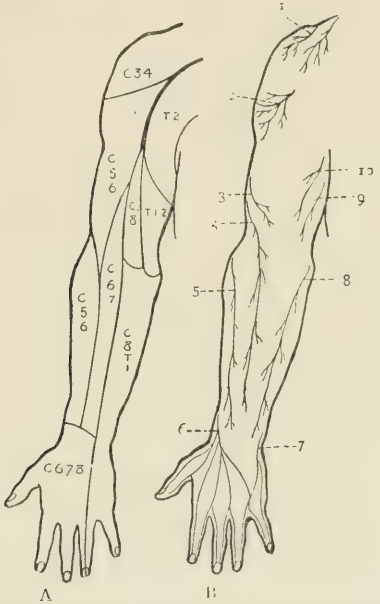


FIG. 67.—The Nerve-supply of the Skin on the Dorsal Aspect of the Upper Limb.

A. The segmental supply.
B. The individual nerves of supply.

1. Posterior supra-clavicular nerves.
2. Lateral cutaneous nerve of arm.
3, 4. Dorsal cutaneous nerve of forearm (upper and lower external cutaneous branches of musculo-spiral nerve).
5. Lateral cutaneous nerve of forearm.
6. Superficial division of radial nerve.
7. Dorsal cutaneous branch of ulnar nerve.
8. Medial cutaneous nerve of forearm (internal cutaneous nerve).
9. Intercosto-brachial nerve.
10. Posterior cutaneous nerve of arm (internal cutaneous branch of musculo-spiral nerve).

cutaneous branch and the digital nerves, and, unless tendons have been divided in addition, deep sensibility is not interfered with. As usual in these cases, the area of epicritic loss

exceeds the area of protopathic loss. It affects the radial part of the palm, the volar aspects of the thumb, index, middle and ulnar half of the ring finger, and the dorsal aspects of the distal halves of the index, middle and ulnar half of the ring finger. The dorsum of the thumb is never affected in injuries to the median nerve.

(*b*) **When the median nerve is divided in the axilla or arm,** all the flexor and pronator muscles are paralysed, except the flexor carpi ulnaris and the ulnar half of the flexor digitorum profundus. The ring and the little fingers retain their lumbricals and interossei, in addition to their profundus tendons, and they are therefore little affected. The middle and index fingers, however, only retain their interossei, as both the flexor digitorum sublimis and profundus and the first two lumbricals are paralysed. They are extended or hyper-extended at the metacarpo-phalangeal joints and extended at the interphalangeal joints. Active flexion of these fingers can only be carried out at the metacarpo-phalangeal joints, and it is then produced by the interossei.

The thumb is maintained extended and adducted. Flexion of the terminal phalanx is impossible and flexion of the proximal phalanx is a weak movement, produced by the unparalysed adductor pollicis. Abduction can be simulated by the abductor pollicis longus, as has been described above, but, owing to the paralysis of the flexor pollicis longus, opposition of any kind, either true or false, is impossible.

The forearm is held in the supine position and, as both the pronator teres and quadratus are paralysed, true pronation is impossible. The brachio-radialis is able to initiate the movement (p. 140), and, if the arm is then abducted to a right angle, the weight of the partially pronated hand can complete the movement.

The *sensory phenomena* are restricted to the same areas as before (*vide supra*), but deep sensibility is absent over the middle and index fingers, and, in many cases, over a wider area, which is more or less co-extensive with the area of protopathic loss.

Segmental Supply of the Muscles of the Upper Limb

Most of the muscles of the upper limb are innervated by more than one segment of the spinal medulla, but the clinical evidence (Kocher, Thorburn, Sherren and others) appears to show that each muscle is dependent on a single segment for its principal action. Thus, the deltoid receives branches from both the fifth and sixth cervical nerves, but it is completely paralysed when the anterior ramus of the fifth is divided. The functions of the additional supply may be sensory or they may be motor, subsidiarily to the main segment, for muscles contract not only when their particular action is desired but also in association with other muscles. For example, when a heavy weight is being carried in the hand, with the arm by the side, the flexors of the fingers apparently do most of the work, but in order to take the strain off the ligaments of the wrist, elbow and shoulder-joints, the flexors and extensors of the wrist and elbow, the deltoid, coraco-brachialis, etc., are all firmly contracted.

The clinical evidence, unfortunately, is not entirely satisfactory, as witnessed by the fact that the leading authorities do not always agree with one another with reference to the main segments for certain muscles. It seems probable that a group of muscles, possessing a common action (*e.g.* flexors carpi radialis and ulnaris, digitorum sublimis and profundus, pollicis longus and palmaris longus all assist in flexion of the wrist-joint), should receive its nerve-supply from a single segment. The segmental supply as put forward by Sherren supports this view. Kocher, on the other hand, has come to the conclusion that the segmental supply of a muscle depends rather on the particular joint on which its principal action depends.

In the present state of existing knowledge, it will perhaps be useful to summarise the different views.

Fifth Cervical Segment.—According to Kocher, this segment is responsible for the supply of (1) the abductors and lateral

rotators of the shoulder, (2) the flexors and supinators of the forearm, and (3) the rhomboids. Sherren's views are substantially in agreement with Kocher's, but Thorburn refers the supra- and the infra-spinatus to the sixth segment.

Sixth Cervical Segment.—To this segment Kocher and Thorburn refer the supply of the muscles which oppose those innervated by the fifth, *i.e.* (1) the adductors and medial rotators of the shoulder, (2) the extensors and pronators of the forearm, and (3) the serratus anterior. Sherren believes that the sixth segment is not so definitely associated with particular muscle-groups, and he only includes in its supply (1) the clavicular part of the pectoralis major, (2) the pronators, (3) the radial extensors of the wrist, and (4) the serratus anterior.

Seventh Cervical Segment.—Kocher includes both the flexor and the extensor muscles of the wrist, but Thorburn only assigns the flexors to this segment. Sherren only agrees with Kocher with reference to the extensor carpi ulnaris and he includes the triceps, the extensor muscles of the fingers and the sterno-costal portion of the pectoralis major. There is, therefore, very little agreement with regard to the individual muscles supplied by the seventh cervical nerve, probably because it is practically never injured alone, since it is the middle, and longest, of the five main nerves which constitute the brachial plexus.

Eighth Cervical Segment.—The flexor and extensor muscles of the fingers are innervated by the eighth cervical segment, according to Kocher, but Sherren includes the flexors only, and, with them, the flexors of the wrist. Thorburn substantially agrees with the latter.

First Thoracic Segment.—According to practically all the authorities, this segment is responsible for the supply of the small muscles of the hand. In view of the comparative unanimity with regard to the fifth cervical segment, it is not surprising to find the same agreement with regard to the first thoracic, because, on account of their shortness, the

anterior rami of C. 5 and T. 1 are subjected to stretching much more frequently than the other nerves of the plexus.

From this summary it may be concluded that existing knowledge of the segmental supply of the upper limb is definite with reference to the fifth cervical and first thoracic segments, but that more data or new methods of examination are required before the muscles associated with the intermediate segments can be definitely determined.

It will be observed, however, that the muscles of the shoulder-girdle and arm are supplied by the upper nerves of the plexus, which take origin from the upper part of the cervical enlargement of the spinal medulla (p. 40), whereas the muscles of the distal part of the limb are supplied by the lower nerves. When acute anterior polio-myelitis affects the cervical enlargement, it is commonly limited to its upper or lower part, and the resulting paralysis is correspondingly of the upper arm or lower arm type.

Segmental Sensory Supply of the Upper Limb

Just as certain segments of the spinal medulla are associated with certain muscle groups, so each segment of the spinal medulla is associated with a certain area of skin, and this fact is best appreciated when the mode of development of the limbs is called to mind.

The limbs arise as lateral buds from the body of the embryo. The upper limb grows out in the lower cervical region at right angles to the long axis of the body, and it contains prolongations of the lower four cervical and the first thoracic segments. It possesses ventral and dorsal surfaces, which are separated by cephalic, or pre-axial, and caudal, or post-axial borders. The anterior rami of the lower four cervical and first thoracic nerves grow out into the bud. The fifth cervical nerve is associated with the pre-axial border, and the first thoracic with the post-axial border, while the intermediate nerves occupy intermediate positions. As the

limb increases in size, the sixth and seventh cervical nerves reach the pre-axial border and the eighth reaches the post-axial border (Fig. 68).

This arrangement is maintained throughout development. In Fig. 67 the segmental distribution of the cutaneous nerves of the upper limb is represented diagrammatically. The fifth and sixth cervical nerves supply the lateral aspect of the arm and forearm; while the seventh does not appear on the volar aspect till the hand is reached. The medial aspect of the limb is supplied by the eighth cervical and the first and second thoracic nerves. On the dorsal aspect of the

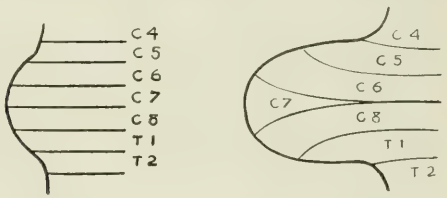


FIG. 68.—Diagram representing the development of the Upper Limb, and the segmental arrangement of its Sensory Nerve-supply.

limb, the arrangement is precisely similar except that the seventh cervical nerve reaches the skin of the forearm. This description is in harmony with the views of Edinger, Purves-Stewart and others, but it is not accepted by Sherren, who holds that the whole of the lateral aspect of the limb is supplied by the fifth, sixth and seventh cervical nerves and that the areas supplied by each are practically co-extensive.

LESIONS OF THE BRACHIAL PLEXUS

In accordance with the segmental motor and sensory supply of the upper limb, it is possible to determine the exact site of injuries of the spinal medulla or of the anterior rami of the spinal nerves in the lower cervical region. Injuries of

the plexus, however, may involve the trunks or cords, and certain facts must be borne in mind when the site of any such lesion is being determined.

When the *fifth cervical segment* is involved, the actions of the rhomboids and the supra- and infra-spinati must be carefully investigated. If the rhomboids are found to be paralysed, then the nerve must be affected close to the intervertebral foramen. If the rhomboids are not involved and the supra- and infra-spinati are paralysed, then the lesion must have caught the nerve just prior to the formation of the upper trunk of the plexus, but if both groups have escaped, the lesion is one of the upper trunk. Unfortunately, it is not easy to ascertain whether these groups are paralysed or have escaped. In the case of the rhomboids, the position of the scapula is altered somewhat on the affected side. It occupies a slightly lower position and, the bone being rotated clockwise (as viewed from in front) by the serratus anterior, the inferior angle is farther from the median plane than it is on the sound side. The examination of the supra-spinatus is rendered difficult because the muscle is almost entirely covered by the trapezius and is nowhere subcutaneous. Fortunately, sufficient of the infra-spinatus is exposed to enable its electrical reactions to be examined.

When the *sixth segment* is involved, the action of the serratus anterior must be tested. Forward pushing movements against resistance make the digitations of origin stand out prominently on the lateral thoracic wall, in moderately well-developed subjects. Ability to flex the shoulder beyond an angle of 90° indicates that the serratus anterior is acting normally. If the serratus anterior is paralysed (p. 132), the sixth cervical nerve is involved close to its exit from the intervertebral foramen.

When the *first thoracic segment* is involved, the condition of the cervical sympathetic gives a clue to the situation of the lesion. When it is affected, the lesion must be situated between the point where the first thoracic nerve gives off its white ramus communicans and the point at which it leaves the vertebral canal.

THE INTERCOSTAL NERVES

The **Anterior Rami** of the upper eleven **Thoracic Nerves** form the **intercostal nerves**; but the first intercostal is very small and only supplies the first intercostal muscles. The second, third, fourth, fifth and sixth not only supply the intercostals but also give off lateral and anterior cutaneous branches. The *lateral cutaneous nerves* pierce the deep fascia near the mid-axillary line, and divide into anterior and posterior branches, which supply the skin over the lateral aspect of the body (Fig. 69). The lateral branch of the second intercostal nerve, however, supplies the skin on the postero-medial aspect of the arm and is termed the **intercosto-brachial nerve**. Near the sternum, the intercostal nerves turn forwards and their terminal branches constitute the *anterior cutaneous nerves*.

In consequence of the areas supplied by the second intercostal nerve, it is not surprising to find that, in the condition of "thoracic-ulnar analgesia," which is frequently an early sign of tabes dorsalis, there is loss of sensibility over the upper part of the chest and the medial side of the arm.

It must be remembered that although the intercostal nerves follow a very oblique course as they pass round the body, their branches descend all to the same level before supplying the skin. Each intercostal nerve is responsible for the supply of a horizontal band of skin, which corresponds in level to the terminal twigs of its cutaneous branches.

The lower five intercostal nerves and the subcostal nerve correspond to the upper intercostal nerves, except that their terminal branches extend beyond the costal margin and gain the anterior abdominal wall. On this account, the anterior abdominal wall is often the site of referred pain in cases of pneumonia and pleurisy. These nerves give off lateral and anterior cutaneous branches, but, in addition to supplying the intercostal muscles, they innervate the rectus abdominis, the internal and external obliques and the transversus muscle.

The *Rectus Abdominis* is a strap-like muscle, which arises from the front of the pubis and extends upwards to the xiphoid process and the adjoining costal cartilages. When it contracts, it helps to flex the vertebral column, but, like the lateral

[*Photo by Alinari.*

FIG. 69.—The Nerve-supply of the Anterior Aspect of the Trunk.

muscles of the abdominal wall, its main action is to assist expiration by compressing the abdominal viscera so that the liver may elevate the relaxed diaphragm. Further, in common with the lateral muscles, the rectus normally influences the muscular tonus of the alimentary canal, and improvement of

the tonus of these muscles is an important step in the treatment of constipation.

The *External Oblique*, the *Internal Oblique* and the *Transversus* are flat, fleshy muscles, which form the lateral portions of the muscular abdominal wall. Anteriorly, where they are related to the rectus, they form thin aponeurotic sheets, which blend with one another and with those of the opposite side in the linea alba. Their functions are the same as those of the rectus, but, whereas the rectus helps to flex the vertebral column in an antero-posterior plane, the obliques help to produce lateral flexion of the vertebral column.

It is important to recognise that the muscles of the anterior and lateral abdominal walls are segmental in origin, *i.e.* the external oblique corresponds to a number of external intercostal muscles fused together into one sheet. These muscles are all supplied by the lower six thoracic and the first lumbar nerves, and each nerve supplies a particular segment. As a result, the muscles are able to contract in segments, and, although this contraction cannot be effected voluntarily, it can be produced reflexly. A localised area of contraction indicates that a "focus of irritation" is present in the particular segment of the spinal medulla which innervates the muscular segment involved, and this focus may be due to irritation of the peripheral sympathetic fibres which are associated with that segment. For example, the upper half of the right rectus is innervated by the seventh, eighth and ninth thoracic nerves, and these segments of the spinal medulla not only innervate the muscle but also receive afferent impulses *via* the sympathetic from the gall-bladder and bile-ducts (p. 264). As a result, cholecystitis is frequently associated with a localised contraction of the upper part of the right rectus muscle.

Similar contracted areas are often found in gastric ulcer (p. 250), appendicitis (p. 279), renal colic (p. 364) and other abdominal conditions.

In *herpes zoster*, the eruption is found to be limited to the area of sensory supply of a given thoracic nerve, and it therefore

forms a horizontal strip round the body. In the girdle pains of *tabes dorsalis*, the pain is experienced in the same horizontal strips, but it is not uncommon for several adjoining areas to be affected at the same time.

Areas of hyperæsthesia are frequently found in the skin of the abdominal wall, and, like the areas of localised muscular contraction, they are due to the presence of a "focus of irritation" (p. 195) in the spinal medulla. The level at which they occur may be of help in determining the diagnosis. It is useful, for this purpose, to remember that the umbilicus lies in the zone supplied by the tenth thoracic nerve, and that the first lumbar nerve is restricted to a very small area in the lowest part of the abdominal wall.

THE LUMBAR PLEXUS

The **Anterior Rami** of the upper four **Lumbar Nerves** take part in the formation of the **Lumbar Plexus**. After leaving the vertebral canal, they enter the substance of the psoas major muscle, where the plexus is formed. Cases of psoas abscess in which the muscle is infiltrated by pus may be accompanied by muscular paralysis or by pain which is referred to the peripheral distribution of the sensory branches of the plexus.

The **Ilio-hypogastric** and the **Ilio-inguinal Nerves** arise from the first lumbar nerve, very often by a common trunk. They appear at the lateral border of the psoas major and run laterally, at first posterior to the kidney. In this part of their course they may be compressed by tumours of the kidney, and the pain is referred to their distribution.

The ilio-hypogastric nerve gives off an iliac branch, which crosses the iliac crest to supply the skin over the lateral part of the buttock, and it then runs forwards, terminating by supplying the skin over the lower part of the rectus muscle (Fig. 69). In addition to its sensory branches, the nerve usually helps to supply the lateral muscles of the abdominal wall.

The ilio-inguinal nerve emerges through the subcutaneous

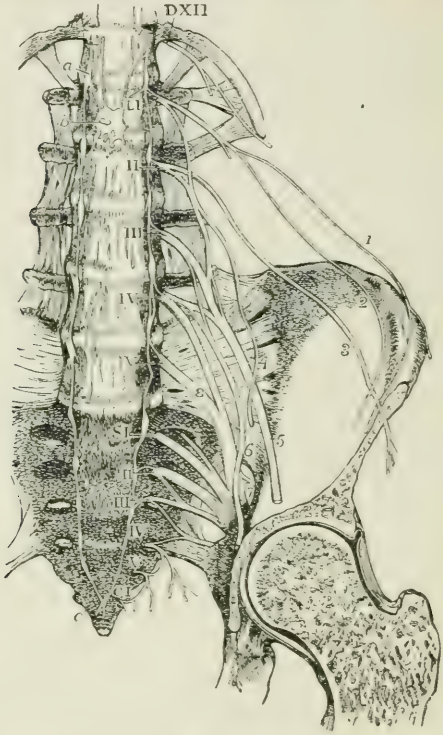


FIG. 70.—The Lumbar, Sacral and Pudendal Plexuses. The abdominal and pelvic portions of the sympathetic trunks are also shown. (TURNER'S *Anatomy*.)

1. Ilio-hypogastric nerve.
2. Ilio-inguinal nerve.
3. Lateral cutaneous nerve of thigh.
4. Genito-femoral nerve.
5. Femoral (anterior crural) nerve.
6. Obturator nerve.
7. Sciatic nerve.
8. L. V joining part of L. IV to form the lumbo-sacral cord.

a. Sympathetic trunk.
b. Cœliac (semilunar) ganglion.
c. Ganglion impar.

inguinal ring (external abdominal ring) and supplies the adjoining area of skin over a limited extent. It may be

compressed against the superior crus (pillar) of the ring by large inguinal herniæ and give rise to painful symptoms.

The **Genito-femoral Nerve** arises from the first and second lumbar nerves, and descends on the surface of the psoas major. It divides into the *lumbo-inguinal* (*femoral branch*) and the *external spermatic nerves* (*genital branch*). The former varies considerably in size. Usually, it supplies a small area of skin just distal to the middle of the inguinal ligament (of Poupart), but occasionally it extends as far as the knee, supplying a large area of skin on the front of the thigh.

The external spermatic nerve enters the spermatic cord and supplies the cremaster muscle, which constitutes one of the coverings of the cord and testis. In addition, it supplies a sensory branch to the tunica vaginalis testis (p. 375) (Mackenzie).

The *Cremaster Muscle* is derived from the lower border of the internal oblique and it consists of a number of muscular loops, of varying size, which pass downwards on the spermatic cord and then ascend to the inguinal ligament (of Poupart). When the muscle contracts, it drags the testis upwards towards the subcutaneous inguinal ring.

The *cremasteric reflex* depends on the integrity of the genito-femoral nerve and the segments of the spinal medulla from which it arises. When the skin of the proximal part of the front of the thigh is lightly stroked, the testis is drawn upwards in the scrotum. This reflex is particularly active in children, but it is not so easy to elicit in the adult. The afferent impulse passes along the lumbo-inguinal nerve and reaches the second lumbar segment of the spinal medulla. From there, the efferent impulse is conveyed to the cremaster muscle by the external spermatic nerve. The cremasteric reflex is increased in lesions of the spinal medulla above the second lumbar segment.

The **Lateral Cutaneous Nerve of the Thigh** arises from the second and third lumbar nerves. After emerging from the psoas major, it crosses the iliacus and reaches the lateral

extremity of the inguinal ligament, behind which it passes to enter the thigh. As it lies on the iliacus, it is placed behind the cæcum, on the right side, and the iliac colon, on the left side of the body. It supplies the skin of the lateral aspect of the thigh and extends as far as the knee-joint. In addition, it gives off branches, which pass backwards to the buttock and back of the thigh.

The **Femoral Nerve (Anterior Crural) (L. 2.3.4.)** is the biggest and most important branch of the lumbar plexus. It enters the thigh behind the inguinal ligament, in the groove between the psoas major and the iliacus, but it supplies the latter muscle before it leaves the pelvis.

In the thigh, it gives off—(*a*) *Motor branches*, which supply the quadriceps femoris, the sartorius and the pectineus; (*b*) *articular branches* to the hip- and knee-joints; and (*c*) the *medial* and *intermediate cutaneous nerves* of the thigh and the *saphenous nerve.*

The Quadriceps Femoris comprises the Rectus Femoris, the Vastus Medialis, Vastus Intermedius (Crureus) and the Vastus Lateralis.

The *Rectus Femoris* arises from the antero-inferior spine of the ilium and is inserted into the proximal border of the patella. It acts as a flexor of the hip and as an extensor of the knee. Consequently, it forms a prominent elevation on the front of the thigh, when the hip-joint is flexed and the knee-joint extended, the limb not being supported.

The three *Vasti* muscles arise from the femur and are inserted into the patella. The Medialis and Lateralis form distinct prominences at the sides of the knee, when they are called on to keep the leg extended against gravity; the elevation produced by the medialis extends more distally than that produced by the lateralis.

The *Sartorius* arises from the antero-superior spine of the ilium and passes distally and medially to reach the medial side of the thigh. It then descends vertically across the medial aspect of the knee-joint and is inserted into the proximal part of the antero-medial surface of the tibia. It acts as a flexor of both the hip- and the knee-joints, and it can be made to stand out when the lower limb, flexed at both joints, is elevated from the ground. Since the sartorius is supplied by the femoral nerve, its action as a flexor of the knee is of special interest (p. 175).

The *Pectineus* lies in the proximo-medial part of the thigh. It arises from the superior ramus of the pubis and is inserted into the posterior

surface of the proximal part of the femoral shaft. As it passes from its origin to its insertion, it crosses the anterior aspect of the capsule of the hip-joint, and it therefore acts as a flexor of that joint. In addition, it is a weak adductor.

The **Intermediate Cutaneous Nerve** of the thigh supplies the skin on the anterior aspect of the thigh and takes part in the formation of the prepatellar plexus. Its area of distribution is overlapped by the medial and the lateral cutaneous nerves and also by the lumbo-inguinal nerve (p. 165).

The **Medial Cutaneous Nerve** of the thigh is distributed to the skin over the medial aspect of the thigh and knee. Its branches overlap not only the branches of the intermediate cutaneous but also the branches of the posterior cutaneous (small sciatic) nerve.

The **Saphenous Nerve** accompanies the femoral artery in the proximal two-thirds of the thigh. It pierces the deep fascia opposite the adductor tubercle and descends along the medial aspect of the leg. Finally it terminates about the middle of the medial border of the foot.

Paralysis of the Femoral Nerve is a very uncommon condition. When the psoas major and the iliacus are involved in addition to the quadriceps, the sartorius and the pectineus, the movements of flexion at the hip and extension at the knee are greatly weakened, but they are not impossible. When the thigh is hyperextended and rotated laterally, the adductors (obturator nerve) and the tensor fasciæ latæ (superior gluteal nerve, p. 172) can produce flexion of the hip and the latter muscle alone is able to extend the knee-joint. On this account, the patient may be able to walk with the help of a stick.

When the femoral nerve is completely divided, sensory disturbances occur in the distal part of the antero-medial aspect of the thigh, and in the medial aspect of the leg and ankle, in the area supplied by the saphenous nerve. It is in the latter area that the greatest alterations in sensibility occur, but deep sensibility is not affected.

The **Obturator Nerve** also arises from the second, third and fourth lumbar segments, but it pursues a different course from that adopted by the femoral nerve. It pierces the medial

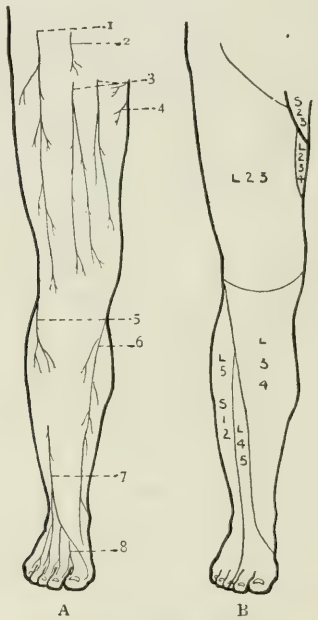


FIG. 71.—The Nerve-supply of the Skin on the Anterior Aspect of the Lower Limb.

A. The individual nerves of supply.
B. The segmental supply.

1. Lateral cutaneous nerve.
2. Lumbo-inguinal nerve (crural branch of genito-crural nerve).
3. Intermediate (middle) and medial cutaneous nerves.
4. Obturator nerve.
5. Lateral sural nerve.
6. Saphenous nerve.
7. Superficial peroneal (musculo-cutaneous) nerve.
8. Medial branch of deep peroneal (anterior tibial) nerve.

border of the psoas major and passes forwards on the lateral wall of the pelvis, just below the brim, lying in the floor of the fossa ovarica in the female (p. 393). It leaves the pelvis by

passing through the uppermost part of the obturator foramen, and in this way it gains the medial compartment of the thigh. The branches of the obturator nerve are distributed (1) to the obturator externus and to the adductor group of muscles; (2) to the hip- and knee-joints; and (3) to the skin over the medial aspect of the thigh.

The *Obturator Externus* arises from the outer surface of the obturator membrane and, passing first below and then behind the capsule of the hip-joint, is inserted into the trochanteric fossa. It is a powerful lateral rotator of the thigh, but its paralysis cannot be satisfactorily demonstrated, because (1) the muscle is so deeply placed that the examination of its contractility or its electrical reactions is practically impossible, and (2) the thigh is furnished with several lateral rotator muscles, *e.g.* obturator internus, quadratus femoris, etc., which are supplied by the sacral plexus.

The *Adductor Group* consists of the Adductors Longus, Brevis and Magnus and the Gracilis.

The *Adductors Longus* and *Brevis* extend from the pubis to the dorsal aspect of the shaft of the femur. They are powerful adductors and they assist in flexing the hyperextended thigh.

The *Adductor Magnus* arises from the pubis and its origin extends backwards on to the ischial tuberosity. It is inserted into the whole length of the dorsal aspect of the femur, and, distally, it reaches the adductor tubercle on the medial condyle. The fibres which arise from the pubis are attached to the proximal part of the femur, whereas those which arise from the ischial tuberosity run almost vertically to gain the adductor tubercle. On account of the arrangement of its fibres, the action of the adductor magnus is slightly complicated.

Acting as a whole, the muscle is a powerful adductor. The upper fibres help to flex the hyperextended thigh, but the lower fibres help to extend the flexed thigh. In consequence of the latter action, the adductor magnus receives an additional nerve of supply, from the sciatic nerve.

The *Gracilis* arises from the pubis and passes distally along the medial aspect of the thigh to be inserted into the proximal part of the antero-medial surface of the tibia. It is a weak adductor and flexor of the hip, but it assists in flexion and medial rotation of the knee (p. 175).

The *Articular Branches* help to supply the synovial membrane of the hip- and knee-joints, but the genicular branch is by no means constant. It appears likely that pain referred from the hip-joint to the region of the knee has no connexion

with the genicular branch of the obturator nerve. The articular branches of the femoral nerve are stimulated on the hip-joint and an "overflow" (p. 191) occurs in the spinal medulla in such a way as to stimulate the cells which receive afferent impulses from the medial and intermediate cutaneous nerves of the thigh. In this way the pain is referred to the region of the knee.

The *Cutaneous Branches* of the obturator nerve supply a small area on the medial aspect of the thigh which is overlapped by the adjoining medial and posterior cutaneous nerves.

The Obturator Nerve may be injured in the pelvis by tumours in connexion with the uterus or rectum, or during the passage of the fœtal head at parturition. The first sign of the involvement of the obturator nerve in these cases is pain which is referred to the medial aspect of the thigh.

When the obturator nerve is completely divided, there is no alteration discoverable in the sensibility of the skin of the thigh, but there is complete paralysis of the adductor muscles, a condition which is best appreciated when the patient is examined lying flat on his back with the lower limbs extended. In this position, the affected limb is maintained in a position of slight abduction by the unopposed abductor muscles. On the other hand, when the patient assumes the erect attitude, the noticeable deformity may be very slight, as the abductor muscles are then opposed by the weight of the limb.

THE SACRAL PLEXUS

The **Sacral Plexus** is formed by a part of the fourth and the whole of the fifth lumbar, the first, second and part of the third sacral nerves. The **lumbo-sacral cord**, which is formed by the union of the fifth lumbar with a branch of the fourth lumbar nerve, unites with the first and second and a branch of the third sacral nerve. In this way a large band is constituted, which, although mainly continued as the *Sciatic Nerve*, gives off several smaller branches.

On the left side, the plexus is situated posterior to the rectum, and this constitutes an important relationship, for the rectum (p. 283) is capable of enormous distension, so that it may com-

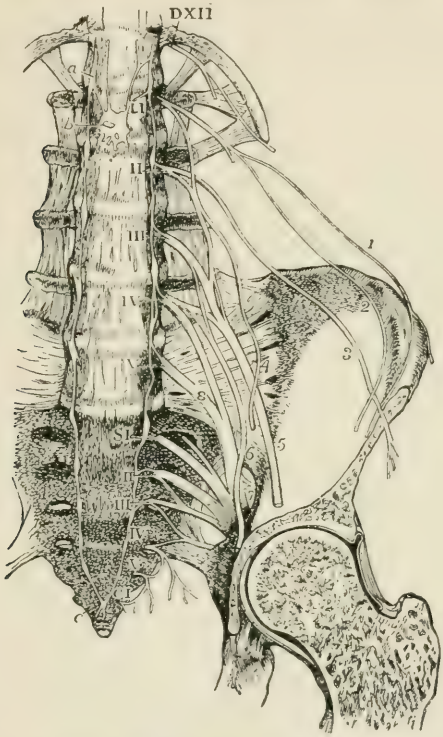


FIG. 72.—The Lumbar, Sacral and Pudendal Plexuses. The abdominal and pelvic portions of the sympathetic trunks are also shown. (TURNER'S *Anatomy*.)

7. Sciatic nerve. 8. L. V joining part of L. IV to form the lumbo-sacral cord.

press not only the left but also the right sacral plexus. As a result, the patient may have all the symptoms of sciatica, and it is of great benefit to make the thorough evacuation of the

rectum a routine measure in the initial stages of treatment of all cases of sciatica.

Owing to its position, the plexus may be injured during parturition in difficult labours.

The **Superior Gluteal Nerve** (L. 4 and 5, and S. 1) arises from the posterior aspect of the plexus and enters the gluteal region by passing through the great sciatic foramen. It gives off no cutaneous branches, but it supplies the glutæi, medius and minimus, and the tensor fasciæ latæ.

The *Glutæus Medius* arises from the dorsum ilii and its fibres converge on the lateral aspect of the greater trochanter of the femur, passing above the capsule of the hip-joint, from which they are separated by the glutæus minimus. The medius acts as a powerful abductor of the thigh; in addition, the anterior fibres act as flexors and medial rotators, while the posterior fibres act as lateral rotators of the hip. The upper and anterior part of the muscle is covered by the skin and fasciæ, but the greater bulk of the muscle is hidden from view by the glutæus maximus.

The *Glutæus Minimus* lies under cover of the preceding muscle and is therefore deeply placed. From their origin on the lower part of the dorsum of the ilium, the fibres converge on the anterior aspect of the greater trochanter where they receive insertion. The action, like the nerve-supply, of this muscle is the same as that of the glutæus medius.

The *Tensor Fasciæ Latæ* arises from the anterior part of the lateral lip of the iliac crest and is inserted into a splitting of the deep fascia on the lateral aspect of the thigh. Through the ilio-tibial tract (band) of the deep fascia, the muscle exercises an extensor action on the knee-joint, and by bracing the tract it helps to relieve the strain from the quadriceps when the erect attitude is maintained. Further, the tensor fasciæ latæ acts as a weak abductor and medial rotator of the hip-joint.

The *Ilio-tibial Tract* (*Band*) is the thickened lateral part of the deep fascia of the thigh. Distally, it blends with the periosteum over the lateral condyle of the tibia and the head of the fibula and proximally it is attached to the lateral lip of the iliac crest. It forms such a strong sheet that extravasations of blood on its deep surface do not rupture through it, but extend distally or forwards before discoloration becomes visible.

The **Inferior Gluteal Nerve** (L. 5 and S. 1 and 2) also arises from the posterior aspect of the plexus and passes through the greater sciatic foramen to enter the buttock, where it is entirely distributed to the *glutæus maximus*. The latter muscle

together with the thick layer of superficial fascia which covers it, forms the normal prominence of the buttock. It has a wide origin from the ilium, sacrum, coccyx and sacro-tuberous (great sacro-sciatic) ligament and its fibres run downwards and laterally to be inserted into the ilio-tibial tract and the dorsal aspect of the proximal part of the femur. The principal action of the muscle is to extend the thigh, but it is also a powerful lateral rotator and an abductor. When the lower limbs are fixed, the glutæi maximi help to extend the trunk on the hip-joints.

The *Quadratus Femoris* is a small muscle, which extends from the lateral border of the ischial tuberosity to the posterior aspect of the proximal part of the femur. It acts as a lateral rotator of the thigh, and is supplied by a special branch from the sacral plexus (L. 4 and 5, and S. 1). The same nerve supplies the inferior gemellus.

The *Obturator Internus* arises from the pelvic surface of the obturator membrane and from the adjoining area of bone. Its tendon leaves the pelvis by passing through the lesser sciatic foramen. In the buttock, the tendon is joined by the two small *gemelli* muscles, which arise from the lesser sciatic notch, and all three have a common insertion into the apex of the greater trochanter. When the thigh is flexed, they help the movement of abduction, but, when the thigh is extended, they assist in lateral rotation. The obturator internus and the superior gemellus are both supplied by a special branch from the sacral plexus (L. 5 and S. 1 and 2), while the inferior gemellus receives its supply from the nerve to the quadratus femoris.

The **Sciatic Nerve** is the largest and most important branch of the sacral plexus. It receives fibres from the fourth and fifth lumbar nerves and also from the first, second and third sacral nerves. Entering the buttock through the greater sciatic foramen, the sciatic nerve descends vertically into the thigh. In its proximal part it lies under cover of the glutæus maximus and, just before it emerges, it is placed mid-way between the ischial tuberosity and the greater trochanter. The nerve is crossed by the long head of the biceps and, in the rest of its course, it is overlapped by the hamstring muscles. The projections formed by the ischial tuberosity and the greater trochanter of the femur protect the nerve from violence, but it may be injured by falls in which the edge of some hard substance

forces its way between the two bony prominences. In its course, the sciatic nerve crosses the posterior (or extensor) aspect of the hip-joint, while its terminal branches are related to the posterior (or flexor) aspect of the knee-joint. On account of these relationships, the sciatic nerve is put on the stretch when the hip-joint is flexed, provided that the knee-joint is in the position of extension. In neuritis of the sciatic nerve, this movement causes intense pain, which disappears on flexion of the knee, on account of the resulting relaxation of the terminal branches.

The Sciatic Nerve terminates about the middle of the thigh by dividing into the **Tibial** (**Internal Popliteal**) and the **Common Peroneal** (**External Popliteal**) **Nerves**, but these two parts, although wrapped up in the same fibrous sheath in the sciatic nerve, are quite distinct from one another right up to their origins from the sacral plexus. In the proximal part of the thigh, the nerve supplies branches to the semimembranosus, the semitendinosus and the long head of the biceps (through its tibial part) and to the short head of the biceps (through its peroneal part). The last-named branch may arise in the distal part of the thigh from the common peroneal nerve itself.

The *Semimembranosus* arises from the ischial tuberosity and passes distally along the medial side of the back of the thigh. It forms one of the proximo-medial boundaries of the popliteal fossa, and its tendon can be readily palpated in that position when the knee is strongly flexed. It is inserted into the posterior aspect of the medial condyle of the tibia.

The *Semitendinosus* also arises from the ischial tuberosity and passes distally on the surface of the preceding muscle. Its tendon can also be palpated at the proximo-medial side of the popliteal fossa, and, finally, it is inserted into the proximal part of the medial surface of the tibia.

Both these muscles act as flexors of the knee and as medial rotators of the leg on the femur.

The *Biceps* has two heads of origin. The long head arises from the ischial tuberosity and the short head from the dorsal aspect of the femur. The tendon of the biceps forms the proximo-lateral boundary of the popliteal fossa and it can he traced distally to its insertion into the head of the fibula, when the knee is strongly flexed. It acts as a flexor of the knee and as a lateral rotator of the leg on the femur.

In addition to acting on the knee-joint, the three preceding muscles act as extensors of the hip-joint, to the posterior aspect of which they are related. It is interesting to observe that, while the thigh may be extended without flexing the knee, the latter joint cannot be flexed unless the hip-joint also is flexed at the same time.

When the hamstrings are completely paralysed, flexion of the knee is still possible but the movement is not a powerful one. It is carried out by the sartorius and the gracilis, which, unlike the other flexor muscles, depend for their nerve-supply on the femoral and the obturator nerves respectively.

The **Tibial Nerve** (**Internal Popliteal**) arises from the sciatic in the middle of the thigh and descends vertically through the popliteal fossa in the middle line of the limb. In the distal part of the fossa, it passes under cover of the superficial muscles of the calf and runs distally to a point mid-way between the medial malleolus and the point of the heel, where it divides into the lateral and medial plantar nerves.

In the popliteal fossa, the tibial nerve gives off—(*a*) *Articular branches* to the knee-joint, (*b*) *motor branches*, and (*c*) the *medial sural nerve* (*ramus communicans tibialis*).

(*b*) The motor branches are supplied to both heads of the gastrocnemius, the plantaris, the popliteus and the soleus.

The *Gastrocnemius* arises by two heads, one from the neighbourhood of each femoral condyle, and these two fleshy bellies are mainly responsible for the formation of the prominence of the calf. About the middle of the back of the leg, they are attached to a common tendon, which is joined at a more distal level by the tendon of the soleus. In this way the tendo calcaneus (Achillis) is formed and it is inserted into the posterior aspect of the calcaneus. When the gastrocnemius contracts, it flexes the knee-joint and plantar-flexes the ankle.

The *Soleus*, which lies under cover of the gastrocnemius and projects beyond its medial border, arises from the posterior aspects of both the tibia and the fibula and unites with the tendon of the gastrocnemius. It acts solely as a plantar flexor of the foot.

The *Plantaris* is a small muscle which arises from the femur, just proximal to the lateral condyle, and is inserted into the calcaneus. It has

a long thin tendon, which is placed between the gastrocnemius and the soleus. Its action is the same as that of the gastrocnemius.

The *Popliteus* arises from the lateral aspect of the lateral condyle, within the articular capsule of the knee-joint. It crosses the lateral aspect of the joint and is inserted into the proximal part of the posterior surface of the tibia. When it contracts, the popliteus flexes the knee and rotates the leg medially on the femur. This muscle is deeply placed, in the floor of the distal part of the popliteal fossa, and its contractions cannot be appreciated on the surface of the limb.

The **Medial Sural Nerve** descends in the interval between the two heads of the gastrocnemius and pierces the deep fascia. It unites with the **ramus anastomoticus peronæus (nervus communicans fibularis)** (p. 178) to form the **nervus suralis (short saphenous)**, and this nerve supplies the skin on the postero-lateral aspect of the leg, the lateral border of the foot and of the little toe.

As the tibial nerve descends through the posterior compartment of the leg, it gives off no sensory branches but it supplies the group of deep muscles, which includes the tibialis posterior, the flexor digitorum and hallucis longus.

The *Tibialis Posterior* arises from the posterior aspects of both bones of the leg and descends behind the medial malleolus. It then passes forwards and is inserted mainly into the tuberosity of the navicular bone, but it gives off additional slips to all the other tarsal bones except the talus and, also, to the middle three metatarsals. When it contracts, the tibialis posterior plantar-flexes the foot and, at the same time, it inverts the foot, *i.e.* lifts the medial border of the foot from the ground so that the sole of the foot looks medially. But, while these movements are the result of the active contraction of the muscle, its normal tonus helps to maintain the arches of the foot.

The *Flexor Digitorum Longus* and the *Flexor Hallucis Longus* arise, respectively, from the posterior aspects of the tibia and of the fibula. They pass behind the medial malleolus and then run forwards in the sole of the foot. Their actions on the digits are clearly explained by their names, but, in addition, they both assist the movement of plantar flexion at the ankle. Further, like the tibialis posterior, they both help to maintain the normal arches of the foot.

The Arches of the Foot.—In order to distribute the weight of the body and to give elasticity to the step in walking and running, the bones of the

foot are arranged to form a *transverse* and an *antero-posterior arch*. The latter is most pronounced along the medial border of the sole and its keystone is formed by the head of the talus (astragalus), which occupies the interval between the sustentaculum tali of the calcaneus (os calcis) and the tuberosity of the navicular (scaphoid). The sustentaculum tali can be felt immediately below the medial malleolus, and the tuberosity of the navicular forms a prominent elevation about $1\frac{1}{4}$ inches farther forwards on the medial border of the foot. The plantar calcaneo-navicular ("spring") ligament extends between these two bones and supports the head of the talus. Although of great strength, it would be unable to support the talus were it not in turn supported by the tendons of certain muscles.

As the tendons of the tibialis posterior, the flexor digitorum longus and the flexor hallucis longus proceed to their respective insertions, they are closely related to the plantar surface of the plantar calcaneo-navicular ligament. Further, the tendons of the two latter muscles cross one another in the sole of the foot, and the tendinous sling so formed gives additional support to the arch of the foot.

So long as the tonus of these muscles is good, the antero-posterior arch of the foot remains intact, but, when the muscles are poorly developed, they become fatigued if called upon to lend support for prolonged periods. In this event, the muscles lose their tonus and become relaxed. As a result, the head of the talus is dependent for its principal support on the plantar calcaneo-navicular ligament, which soon stretches. The head of the talus thus sinks downwards and the antero-posterior arch of the foot collapses.

The *transverse arch* of the foot is most pronounced opposite the bases of the metatarsal bones and it depends for its support principally on the peronæus longus (p. 179).

In the condition of flat-foot, both arches disappear and the elastic spring of the step is entirely lost.

After giving off the **Medial Calcanean Nerve**, which arises near the ankle-joint and supplies a variable area of skin over the medial aspect of the heel, the tibial nerve terminates, about midway between the medial malleolus and the point of the heel, by dividing into the medial and lateral plantar nerves.

The distribution of the **Medial Plantar Nerve** in the foot corresponds fairly accurately to the distribution of the median nerve in the palm of the hand. It supplies four of the small muscles of the sole, but its sensory branches are of greater importance than its motor branches. The *cutaneous branches*

supply the medial half of the sole of the foot and the medial three and a half digits (cf. Median Nerve, p. 151).

The distribution of the **Lateral Plantar Nerve** in the foot corresponds, in a similar manner, to the distribution of the ulnar nerve in the palm of the hand. It gives off numerous motor branches, and its *cutaneous branches* supply the lateral half of the sole of the foot and the lateral one and a half digits (cf. Ulnar Nerve, p. 145).

There is little of practical importance in connexion with the individual muscles of the sole of the foot and, in consequence, no description of them will be given.

The **Common Peroneal Nerve** (**External Popliteal**) arises from the sciatic in the middle of the thigh and runs distally and laterally through the popliteal fossa, in close relation to the tendon of the biceps. It passes behind the head of the fibula and then runs forwards across the lateral aspect of the neck of the bone. In both situations it can be palpated, and it is therefore exposed to injury from bruising, etc. Just distal to the head of the fibula, the common peroneal nerve ends by dividing into the **superficial** (**musculo-cutaneous**) and the **deep peroneal** (**anterior tibial**) **nerves.**

In the popliteal fossa, the common peroneal gives off no muscular branches, but it gives origin to two cutaneous nerves. The **lateral sural nerve** runs forwards and distally to supply the skin on the front of the leg (Fig. 73); the **ramus anastomoticus peronæus** (**ramus communicans fibularis**) passes distally over the lateral head of the gastrocnemius, and unites with the medial sural nerve to form the **nervus suralis** (p. 176).

The **Superficial Peroneal** (**Musculo - cutaneous**) **Nerve** enters the lateral compartment of the leg and supplies the peronæus longus and brevis. It pierces the deep fascia at the junction of the distal and middle thirds of the leg, and is continued on to the dorsum of the foot, to which it supplies some small cutaneous filaments. Its terminal branches supply the medial side of the hallux and the contiguous sides of the second, third, fourth and fifth toes (Fig. 73).

The *Peroneus Longus* arises from the lateral aspect of the fibula and descends behind the lateral malleolus. It then passes forwards on the lateral aspect of the calcaneus below the trochlear process (peroneal

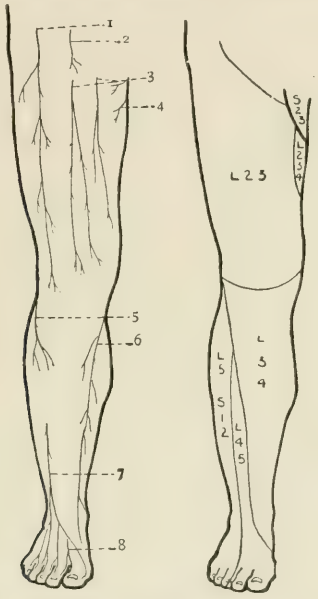


FIG. 73.—The Nerve-supply of the Skin on the Anterior Aspect of the Lower Limb.

A. The individual nerves of supply.
B. The segmental supply.

1. Lateral cutaneous nerve.
2. Lumbo-inguinal nerve (crural branch of genito-crural nerve).
3. Intermediate (middle) and medial cutaneous nerves.
4. Obturator nerve.
5. Lateral sural nerve.
6. Saphenous nerve.
7. Superficial peroneal (musculo-cutaneous) nerve.
8. Medial branch of deep peroneal (anterior tibial) nerve.

tubercle), and, entering a groove on the plantar aspect of the cuboid, it passes across the sole of the foot to be attached to the base of the first metatarsal and the adjoining portion of the medial cuneiform bone. It bridges across the extremities of the transverse arch of the foot, and so constitutes a strong support (p. 176).

The *Peronæus Brevis* has a similar origin, but it passes above the trochlear process and is inserted into the tubercle on the base of the fifth metatarsal bone. Both these muscles act as plantar flexors of the foot, but, at the same time, they elevate the lateral border of the foot from the ground, *i.e.* they act as powerful evertors. When they are brought into action, a distinct furrow is produced on the lateral aspect of the leg and, in the bottom of this furrow, the contracted muscular bellies can be felt. The tendons also can be palpated as they cross the lateral aspect of the calcaneus (os calcis), just distal to the lateral malleolus.

The **Deep Peroneal Nerve** enters the anterior compartment of the leg and is, at first, very deeply placed. As it descends, it supplies branches to the neighbouring muscles and, opposite the ankle-joint, it divides into lateral and medial branches, which extend on to the dorsum of the foot. The *lateral branch* is mainly distributed to the extensor digitorum brevis, but the *medial branch* runs forwards to supply the contiguous sides of the hallux and second toe.

The *Tibialis Anterior* forms the muscular prominence in the proximal part of the anterior compartment of the leg. It arises from the tibia and its tendon passes distally and medially, crossing the anterior aspect of the ankle-joint, to be inserted into the base of the first metatarsal and the medial cuneiform bone. The tibialis anterior acts as a powerful dorsi-flexor and, in company with the tibialis posterior, as a powerful invertor of the foot.

The *Extensor Hallucis Longus* and the *Extensor Digitorum Longus* arise from the fibula and pass distally in front of the ankle-joint. The former is inserted into the base of the terminal phalanx of the hallux, and the latter divides into four tendons, which are inserted into the lateral four toes in the same manner as the tendons of the extensor digitorum communis in the fingers.

Both these muscles dorsi-flex the foot in addition to extending the toes.

The *Peronæus Tertius* arises from the distal part of the fibula and its fleshy belly is continuous with that of the extensor digitorum longus. It crosses the anterior aspect of the ankle-joint and is inserted into the dorsum of the base of the fifth metatarsal bone. Its principal action is to assist in dorsi-flexion of the foot, but it also helps in the movement of eversion.

The *Extensor Digitorum Brevis* is a small muscle, which arises from the anterior part of the upper surface of the calcaneus (os calcis). When the toes are strongly extended, it forms a small elevation, a little in front of the lateral malleolus. It gives origin to four tendons, which pass to the medial four digits.

Affections of the Sciatic Nerve or of its numerous branches are by no means uncommon. The main trunk is pro-

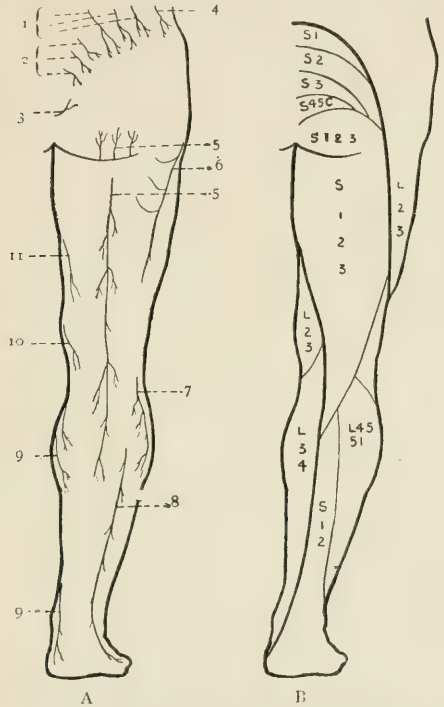


Fig. 74.—The Nerve-supply of the Skin on the Posterior Aspect of the Lower Limb.

A. The individual nerves of supply.
B. The segmental supply.

1. Posterior rami of L. 1, 2 and 3.
2. Posterior rami of S. 1, 2 and 3.
3. Sacro-coccygeal nerve.
4. Iliac branch of ilio-hypogastric nerve.
5. Posterior cutaneous nerve of thigh (small sciatic nerve).
6. Lateral cutaneous nerve of thigh.
7. Lateral sural nerve.
8. Nervus suralis.
9. Saphenous nerve.
10. Medial cutaneous nerve of thigh.
11. Obturator nerve.

vided with a thick, fibrous sheath, which is the site of inflamma-

tion in *sciatica*. In this condition, the sciatic nerve is tender on deep pressure, and subjective symptoms are experienced over the distribution of its sensory branches, usually over the areas supplied by the lateral sural nerve and the nervus suralis (Fig. 74). When the nerve-sheaths are much thickened as the results of the inflammation, the cutaneous branches are nipped as they pierce the deep fascia, giving rise to the "tender points of Valleix." It should be observed that when the condition is due to a localised neuritis of the sciatic nerve, no subjective symptoms are felt in the skin area which is supplied by the posterior cutaneous (small sciatic) nerve (Fig. 74). On the other hand, when the condition is due to intra-pelvic pressure, this area is quite likely to be affected.

When the sciatic nerve is completely paralysed, the *motor symptoms* are very striking. All the muscles distal to the knee are paralysed, and movements of the ankle, foot and toes are quite impossible. In addition, the hamstring muscles are affected, but this does not produce such a striking change, as the knee can be flexed by means of the gracilis and the sartorius (obturator and femoral nerves, respectively).

The amount of *sensory loss* is relatively smaller. The posterior aspect of the leg in its proximal part is supplied by the posterior cutaneous nerve of the thigh (small sciatic), and the medial aspects of the leg and foot are supplied by the saphenous nerve. As a result, the area of sensory loss is restricted to the lateral aspect of the leg, the dorsum of the foot, except near the medial border, and the sole of the foot. Despite the position of the lesion, deep sensibility is only affected in the distal part of the foot (Sherren).

It is interesting to observe that, when the sciatic nerve is injured as the result of stab or gunshot wounds, the fibres affected are in 90 per cent. of cases (Makins) those of the peroneal portion of the nerve, but no adequate explanation can yet be offered to account for this peculiarity.

The **Posterior Cutaneous (Small Sciatic) Nerve** of the thigh (S. 1, 2 and 3) arises from the posterior aspect of the

sacral plexus and enters the buttock through the great sciatic foramen. Beyond the lower border of the glutæus maximus, the nerve descends immediately under the deep fascia. It supplies branches to the skin on the posterior aspect of the thigh, over the popliteal fossa, and over the proximal part of the posterior aspect of the leg. This nerve is derived from segments of the spinal medulla which are accustomed to receive impulses *via* the sympathetic from the lower part of the rectum and the upper part of the anal canal, and from the internal trigone of the bladder. In most cases in which a "focus of irritation" (p. 195) is established in the mid-sacral region of the spinal medulla, the referred pains are experienced in the perineum, but in some cases the pain is referred to the posterior aspect of the thigh, and the condition may be mistaken for sciatica, unless the sciatic nerve is subjected to local examination by deep pressure.

THE PUDENDAL PLEXUS

The **Pudendal Plexus** is formed by portions of the second, third and fourth sacral nerves. Like the sacral plexus, it lies in front of the sacrum and behind the rectum, and it is therefore subject to the same varieties of intra-pelvic pressure (p. 171).

The **Pudendal (Internal Pudic) Nerve** (S. 2, 3 and 4) is the most important branch of the pudendal plexus. It arises in the pelvis and enters the lateral wall of the ischio-rectal fossa, where it gives off the *inferior hæmorrhoidal nerve*, and divides into the *perineal nerve* and the *dorsal nerve of the penis* (or *clitoris*).

The **Inferior Hæmorrhoidal Nerve** is distributed to the external sphincter muscle and to the skin around the anus. In the condition of anal fissure, the external sphincter becomes reflexly contracted owing to the tearing of the mucous membrane, which receives its nerve-supply from the same source (p. 284).

The **Perineal Nerve** contains both motor and sensory fibres. The former supply the levator ani and the muscles of the urogenital triangle of the perineum, *i.e.* the sphincter (compressor) urethræ, the ischio- and the bulbo-cavernosus (the erector penis and the ejaculator urinæ) and the transverse perineal muscles. The sensory fibres supply the skin of the perineum anterior to the anus, including the skin of the scrotum. In addition, they supply the bulb of the penis and the corpora cavernosa.

The **Dorsal Nerve of the Penis** supplies the whole of the skin covering the penis, including the deep surface of the prepuce and the surface of the glans.

Referred pain may be experienced in the perineum, scrotum and penis, in pathological conditions of the viscera which are innervated by the sacral segments of the spinal medulla. It is especially common in vesical calculi, but it also occurs in inflammatory or irritative conditions of the lower part of the rectum, the anal canal, the prostate and the seminal vesicles.

The **Perforating Cutaneous Nerve** (S. 2 and 3) pierces the sacro-tuberous (great sacro-sciatic) ligament and the lower border of the glutæus maximus, and supplies the skin of the buttock in the neighbourhood of the coccyx.

The **Perineal Branch of the Fourth Sacral** helps to supply the external sphincter.

In addition to the named branches, the pudendal plexus gives off branches of supply to the levator ani and the coccygeus. These two muscles form the floor of the pelvis and shut it off from the ischio-rectal fossæ. The *levatores ani* arise from the pelvic wall and project downwards and inwards to meet one another. They are attached to a median raphe, which extends from the tip of the coccyx to the posterior aspect of the anal canal, and they constitute a muscular bed on which the terminal part of the rectum lies as it runs horizontally forwards (p. 283). The anterior fibres, which arise from the pelvic surface of the pubis, pass downwards and backwards; some of them blend with the muscular wall of

the anal canal, while others pass lateral to the rectum and support the angle of union between the rectum and the anal canal. When the levator ani contracts, it forms an unyielding floor against which the pelvic viscera may be compressed by the action of the abdominal muscles during defæcation. Further, the anterior fibres hold the anal canal steady, when a fæcal mass is passing through it.

THE SYMPATHETIC NERVOUS SYSTEM

The sympathetic nervous system is subsidiary to the central nervous system, and the fibres which it distributes and the fibres which it receives are governed ultimately by nerve-cells in the cerebral cortex.

The system consists of two *trunks* (*cords*), one on each side of the body, which extend through the neck, thorax, abdomen and pelvis, and each trunk possesses numerous ganglia, which are interconnected by nerve-fibres. A typical *ganglion* corresponds to one segment of the spinal medulla and is connected to the anterior ramus (primary division) of the spinal nerve of that segment by means of a *grey ramus communicans*.

The grey rami communicantes contain fibres which are passing from the sympathetic to the spinal nerves. When they reach the nerve, some of the fibres pass centrally to the spinal medulla, while others pass peripherally to be distributed by the nerve to the blood-vessels, sweat glands, etc. Efferent fibres from the central nervous system to the sympathetic do not run in the grey rami. They are found in the *white rami communicantes*, which are limited to certain ganglia.

The white rami communicantes connect T. 1 or 2 – L. 1 or 2 and S. 2, 3 and 4 with the corresponding sympathetic ganglia, and, in addition to efferent fibres, they contain the afferent fibres from the viscera. They are not present in the cervical region, and, therefore, the fibres which are distributed by the cervical ganglia must descend through the cervical portion of the spinal medulla and join the sympathetic *via* the

highest white ramus (T. 1 or T. 2, as the individual case may be). It follows, therefore, that in complete lesions of the spinal medulla above the first thoracic segment, the whole of the sympathetic system is cut off from the controlling influence of the cerebral cortex.

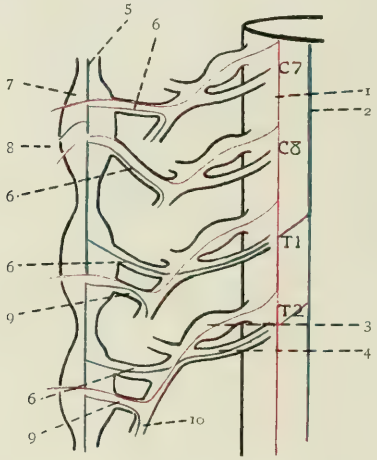


FIG. 75.—Diagram of the Sympathetic Nervous System.

Efferent fibres from the spinal medulla to the sympathetic are shown in blue. Afferent sympathetic fibres are shown in red.

1. Afferent sympathetic fibres.
2. Efferent sympathetic fibres.
3. Posterior nerve-root of T. 2.
4. Anterior nerve-root of T. 2.
5. Efferent sympathetic fibres ascending cervical part of sympathetic trunk.
6. Grey ramus communicans.
7. Inferior cervical ganglion.
8. Cardiac branch from 7.
9. White ramus communicans.
10. Anterior ramus (primary division) of T. 2.

In the cervical region, the sympathetic ganglia are three in number. The **superior cervical ganglion** communicates with the upper four cervical nerves by means of grey rami communicantes. It distributes branches to all the blood-vessels, sweat glands, salivary glands, etc., of the head and neck. Some of these branches issue from the upper end of the ganglion and enter

the interior of the skull in company with the internal carotid artery. The most important of these join the semilunar (Gasserian) ganglion and are carried by the naso-ciliary branch of the ophthalmic nerve (p. 66) to the ciliary ganglion, from which they pass forwards to the eyeball to supply the dilator muscle of the pupil. Paralysis of this muscle is an important sign in affections of the sympathetic (p. 189).

The **middle** and **inferior cervical ganglia** give off grey rami communicantes, which join the fifth and sixth and the seventh and eighth cervical nerves, respectively. In this way, the blood-vessels and sweat glands of the upper limb are brought under the control of the sympathetic system.

In addition, each cervical ganglion gives off a *cardiac branch* and these branches constitute the *accelerator nerves of the heart* (p. 308).

The sympathetic trunk enters the thorax by crossing the anterior aspect of the neck of the first rib and then descends in front of the heads of the ribs. It posseses eleven or twelve **thoracic ganglia**, and each of these is connected to the intercostal nerve to which it corresponds by both a white and a grey ramus communicans. As already stated, the white rami contain efferent fibres from the spinal medulla to the sympathetic system, and they occur throughout the thoracic region, with the occasional exception of the first thoracic segment. These efferents from the spinal medulla have to supply a very large area, since there are no white rami communicantes in the cervical or in the lower lumbar region. They ascend through the cervical part of the sympathetic trunk, through which they are distributed to the head and neck and upper limb.

Other sympathetic efferents arise from the thoracic ganglia and pass to be distributed to the contents of the abdomen. They form the **splanchnic nerves** and the largest of them receives branches from the fifth to the tenth thoracic ganglia, inclusive. The smaller splanchnic nerve arises from the tenth and eleventh and the smallest from the eleventh ganglion.

The greater and smaller splanchnics descend through the thorax and pierce the crus of the diaphragm. On the abdominal surface of the latter, they join the large *cœliac* (semilunar) *ganglion*, which is a subsidiary sympathetic ganglion. The two cœliac ganglia are connected to one another by numerous branches, which are closely associated with the cœliac artery and its branches. From the ganglia visceral branches arise and travel on the coats of the arteries to be distributed to the abdominal viscera. The precise innervation of the viscera is dealt with under the individual organs.

In the abdomen, the sympathetic trunk lies on the sides of the bodies of the lumbar vertebræ. There are usually five **lumbar ganglia**, and, while each possesses a grey ramus communicans, only the first and, sometimes, the second possess white rami communicantes. Most of the efferent fibres of the latter are carried off by the femoral and obturator nerves to supply the blood-vessels, etc., of the lower limb, while others have a similar distribution in the walls of the abdomen.

In the pelvis, the sympathetic trunks lie in front of the sacrum, medial to the anterior sacral foramina, and in front of the coccyx they unite with one another in the *ganglion impar*. There are usually five **sacral ganglia** and, though each possesses a grey ramus communicans, the white rami are restricted to the second and third, or, in some cases, to the third and fourth ganglia.

A large plexus is developed in connection with the sympathetic in front of the promontory of the sacrum. It is termed the **hypogastric plexus** and it is formed by (1) fibres from the aortic plexus, which is a downward continuation of the plexus connecting the cœliac ganglia; (2) branches from the lumbar ganglia; (3) branches from the sacral ganglia. By means of this plexus the white rami communicantes of the mid-sacral region are distributed to the pelvic viscera, the rectum, anal canal, bladder, prostate, etc.

Lesions of the Sympathetic System fall into two groups.

In the first, the lesion affects the spinal medulla, and the sympathetic and the cerebro-spinal systems are involved together. With regard to both systems, the amount of paralysis depends on the nature and the level of the lesion. The whole of the sympathetic system is paralysed in complete lesions of the spinal medulla above the level of the first thoracic segment, but the amount of paralysis is much less when the injury occurs in the thoracic or lumbar regions (p. 190).

In the second group, the sympathetic trunk is itself involved. The lesion is usually due to the pressure of a tumour growth and is consequently unilateral in most cases.

(*a*) *When the sympathetic trunk is involved between the superior and the middle cervical ganglia*, the sympathetic supply to the head and neck is entirely cut off and the condition gives rise to certain well-marked and easily recognisable symptoms, of which the most important are those in connection with the eye. (1) The dilatator pupillæ muscle is paralysed and the pupil on the affected side is therefore definitely contracted. (2) In addition, owing to paralysis of the ciliary bundle (p. 210), pseudo-ptosis develops together with apparent narrowing of the palpebral fissure. (3) These features are accompanied by a slight degree of enophthalmos, for which no very satisfactory explanation has yet been brought forward. (4) All the blood-vessels of the affected side of the head and neck become dilated, and the resulting vascular engorgement is seen best in the conjunctiva. (5) The salivary and lacrimal secretions are usually increased in quantity in the first instance, but they may be deficient or even absent at a later period. (6) The affected areas of skin become dry and rough, owing to paralysis of the sweat-secreting glands.

It should be remembered that tumour pressure at first produces an irritative lesion, causing stimulation rather than paralysis of the sympathetic. In this event, the above-described chain of symptoms is reversed. The pupil is widely dilated, the skin areas sweat profusely, etc.

(*b*) *Lesions occurring at the middle cervical ganglion*, or

between it and the inferior cervical ganglion, produce precisely the same symptoms as in (*a*), but, in addition, the blood-vessels and sweat glands of a part or parts of the upper limb are affected.

(*c*) *Lesions occurring at the inferior cervical ganglion*, or between it and the first thoracic ganglion (or the second, as the case may be), cut off the sympathetic supply of the whole of the upper limb and of the head and neck, on the same side.

(*d*) *Lesions affecting the sympathetic trunk in the thoracic region* only involve the particular segment or segments in which they are situated, as each ganglion possesses its own white ramus communicans. They therefore produce no characteristic or widespread symptoms.

(*e*) In the same way, *lesions occurring in the lumbar or sacral part of the sympathetic trunk* are definitely limited in their effects to the regions supplied by the ganglia involved.

In the abdomen, however, the cœliac ganglia and plexus (p. 188) may not only be affected by tumours in connexion with the viscera in their neighbourhood, but they themselves may be the site of tuberculous disease. Certain cases of Addison's disease have been recorded in which, at the subsequent post-mortem examination, such a condition was found to be present, while the supra-renal glands were perfectly normal (p. 408).

Referred Pain

The Viscero-sensory Reflex.—It has been recognised for many years that painful sensations may be experienced in some area or areas remote from the exciting cause, but it is only recently that the importance of such *referred pains* has been realised.

The simplest instances of referred pain are found when stimulation of one sensory branch of a spinal nerve produces painful sensations in the area supplied by another sensory branch of the same nerve. The classical example occurs in tuberculous disease of the hip-joint. In this case the patho-

logical process stimulates the articular branches of the femoral (anterior crural) nerve, but the pain of which the patient complains is referred to the region of the knee, which also receives branches from the same nerve (Fig. 73).

It is by no means certain by what sequence of events a referred pain is produced. Mackenzie, to whom we are indebted for most of our knowledge on this subject, suggests

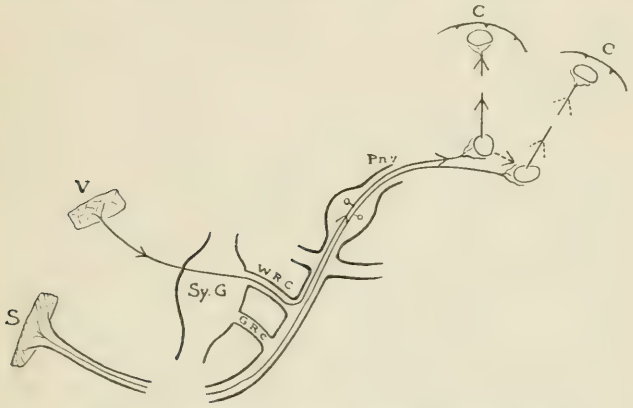


FIG. 76.—Diagram to explain a Viscero-sensory Reflex.

The plain arrows indicate the path of afferent impulses from the viscus; the dotted arrows indicate the "overflow" stimulus.

C. Cortex.
P.n.r. Posterior nerve-root.
W.R.C. White ramus communicans.
G.R.C. Grey ramus communicans.
Sy. G. Sympathetic ganglion.
V. Viscus. *S.* Skin.

that abnormal afferent impulses may not only stimulate the nerve cells for which they were originally intended, but may "overflow" and so stimulate other nerve-cells in their neighbourhood. The effect produced by this "overflow" stimulation will be the same as if the cells had received an impulse from the nerve-fibres with which they are associated. In both methods of stimulation, the impulse which ascends to the cortex is interpreted in the same way and, if the cells affected by the "overflow" normally receive afferent stimuli from a cutaneous

nerve, the interpretation will be a painful sensation in the area supplied by that nerve. It is at present impossible to say whether this theory is correct or not, but at least it offers a reasonable working hypothesis.

A precisely similar sequence of events may occur in connexion with any of the sensory cerebral nerves. Thus, stimulation of one of the terminal branches of the inferior alveolar (dental) nerve by an abscess at the root of a tooth may produce not only toothache but also referred pain in the external acoustic (auditory) meatus (auriculo-temporal nerve, p. 75).

Referred pains may be excited not only by pathological processes affecting structures supplied by cerebro-spinal nerves, but also in the case of structures which receive their nerve-supply from the sympathetic system. For example, in attacks of *angina pectoris* the pain frequently spreads from the præcordia to the medial side of the upper limb, and, in rare cases, it may commence in the upper limb and spread to the chest. The pain in the upper limb is unquestionably a referred pain and it may be accounted for by the "overflow" hypothesis. Afferent impulses from the heart pass *via* the sympathetic to the spinal medulla, where they terminate in connexion with nerve-cells in the upper thoracic segments (p. 307). These segments also contain the cells which receive afferent sensory impressions from the medial side of the arm. Under normal conditions the afferent impulses from the heart do not "overflow," but, in angina pectoris, the impulses are *abnormal* in character and they "overflow" so as to stimulate those neighbouring nerve-cells which are concerned in the cutaneous supply of the medial side of the upper limb. To this sequence of events Mackenzie has given the name of "**viscero-sensory reflex.**"

It is clear that viscera may give rise to referred pains, and it is therefore important to differentiate, if possible, between referred pains and pains actually experienced in the viscera themselves, but attempts to do so meet with numerous

difficulties. Muscles and fasciæ, though not so acutely sensitive as the skin, may be the site of painful sensations and, therefore, abdominal pain felt on a deeper level than the skin is not necessarily experienced in an abdominal viscus. Mackenzie has come to the conclusion that the viscera themselves are insensitive to painful stimuli and that they can only give rise to pain through a viscero-sensory reflex. He has been able to adduce a large mass of evidence in support of this view, but it is opposed by evidence which is difficult to controvert.

The investigation of the question is necessarily carried out, for the most part, on patients who are quite devoid of anatomical knowledge, and the difficulty they experience in localising abdominal pains is increased thereby. This difficulty is caused by the presence of the abdominal walls, which conceal the viscera, and by the absence in the viscera of any sense corresponding to the muscle and joint sense in the limbs. A healthy person is not conscious of his viscera, as the nervous mechanism which controls them is, for the most part, entirely automatic. On the other hand, a healthy person is always conscious of the position of those parts of the body which are supplied by cerebro-spinal nerves. If one attempts to localise the exact position of a painful area in the hand through a piece of wood or some other solid object, it is found that such localisation, though aided by muscle and joint sense, is by no means accurate. In the light of this experiment, one can appreciate the difficulty of localising an abdominal pain, if one assumes that the pain is felt only in the viscus and that the sensibility of the abdominal wall is not affected. Consequently, when a painful area indicated by a patient does not exactly correspond in size or position to the viscus in which it is supposed to originate, it does not necessarily follow that the pain is not felt in the viscus itself.

Further, many medical men, who have suffered from colitis or some other painful condition of the large intestine, state

with confidence that they can trace the pain from the cæcum to the rectum, and that it follows the actual course of the bowel.

On the other hand, cases in which abdominal operations have been performed without the use of a general anæsthetic show that the viscera may be clamped, cut or sutured without giving rise to any painful impressions. In a case operated on by Mackenzie without an anæsthetic of any kind, the patient suffered pain periodically, and it was observed that the pain synchronised with peristalsis affecting a clamped portion of small intestine. The patient, however, localised the pain to an area of the abdominal wall several inches removed from the piece of gut in question. It seems highly probable that this was an example of the viscero-sensory reflex, although it is possible that the mal-reference by the patient was owing to lack of localising sense.

The arm pain in angina pectoris (p. 309) and the testicular pain in renal colic (p. 364) are both undoubtedly referred pains, and it is not illogical to assume that the chest pain in the former and the abdominal pain in the latter are of a similar nature.

The relation which exists between the nerve-supply of the viscera and the nerve-supply of the skin of the trunk is a further argument in favour of Mackenzie's view that the viscera are insensitive to painful stimuli. When the segments of the spinal medulla which are responsible for the sensory supply of the skin of the thoracic and abdominal parietes are compared with those which are connected with the sympathetic system by means of white rami communicantes (p. 185), it is found that they are practically identical. The lower lumbar nerves give off no white rami to the sympathetic and they are not represented in the skin-supply either of the abdominal wall proper or of the perineum, which forms a part of the abdominal wall. Further, only those sacral nerves which possess white rami communicantes take part in the sensory supply of the perineum and the external genitalia.

This relationship between the nerve-supply of the skin of the trunk and the nerve-supply of the viscera suggests a very intimate connexion between the viscera and the covering parietes.

It may be pointed out that viscera which contain muscle fibres give rise to pain of much greater severity and with much more frequency than viscera which contain few or no muscle fibres. A striking contrast exists between the intense pain which may be caused by a minute calculus in the pelvis of the ureter and the entire absence of pain in advanced disease of the liver, lungs or kidneys.

Enough has been said to make it clear that any viscus may give rise to the viscero-sensory reflex, and it is equally clear that our knowledge of this important subject is as yet very deficient.

"**A Focus of Irritation.**"—When a viscero-sensory reflex is established in connexion with a pathological process in a viscus, the stream of abnormal afferent impulses from that viscus and the constant "overflow" may cause a temporary increase in the excitability of the nerve-cells secondarily affected. This condition has been termed by Mackenzie a "focus of irritation." As a result of the increased excitability, an exaggerated interpretation is given to ordinary stimuli passing through the affected cells. For example, if a "focus of irritation" is set up in the eighth thoracic segment by a gastric ulcer, the result may be an increase in the excitability of the nerve-cells which are accustomed to receive impulses from the terminal branches of the eighth intercostal nerve. When this is the case, it is found that an area of *cutaneous hyperalgesia* is present in the epigastric region, *i.e.* gentle stroking of the skin over a certain area gives rise to a feeling of discomfort or pain, because the afferent impulse from the skin becomes exaggerated in its passage through the cells which are in a state of increased excitability. The discovery of such an area is of value, because, when the spinal nerve which supplies it is known, the site of the

"focus of irritation" can be determined and this will help to identify the viscus at fault.

Owing to the limited extent of the spinal medulla, the visceral centres are not placed each in a separate segment, so that two or more visceral centres may occupy the same segment or series of segments. For example, the centre for the stomach is situated in the fifth to the eighth thoracic segments, while that for the liver and gall-bladder occupies the seventh to the tenth thoracic segments. Consequently, when a "focus of irritation" arises in the seventh and eighth thoracic segments, owing to a pathological condition of the gall-bladder, the adjoining cells of the centre for the stomach may be thrown into a condition of increased excitability. In this event the afferent impulses which ascend from the stomach after the ingestion of food become altered as they pass through the "focus of irritation." As a result, although the stomach itself is perfectly healthy, food may be vomited immediately after it has been taken. Similarly, a "focus of irritation" in the lower thoracic region may account for frequency of micturition in some cases of appendicitis.

It must be remembered that the viscera acquire their nerve-supply at an early period of their development and, therefore, those viscera which develop in the median plane are innervated by both sides of the spinal medulla. At a later date, certain of these viscera, *e.g.* the stomach, take up a permanent position to one side of the median plane, while others, *e.g.* the coils of small intestine, vary in position from time to time. It would appear that, in the former case, the viscus loses, or neglects to use, the nerves from the opposite side of the spinal medulla, whereas, in the latter case, the innervation from both sides is retained. As a result, referred pains from the stomach, gall-bladder, etc., are not experienced in the median plane, as they are in the case of the small intestine. It is impossible, however, to be dogmatic upon this aspect of the subject, as our present knowledge is very incomplete.

Viscera which develop to one side of the median plane, *e.g.* the ureters, are innervated from the same side of the spinal

medulla, and, when they give rise to referred pain, the pain is always experienced on the same side of the body and never spreads to the opposite side.

The Viscero-motor Reflex.—Pathological processes which give rise to pain are frequently accompanied by muscular contractions. This association is well seen in tuberculous disease of the cervical vertebræ, in which the rigidity of the muscles of the back of the neck is a striking feature. The muscular contraction is quite involuntary, and it may be explained as a result of the "viscero-motor reflex" of Mackenzie.

In order to account for the viscero-motor reflex, it is necessary to assume that the afferent pathological impulses "overflow" so as to affect the cells round which the fibres of the pyramidal tract (p. 37) arborise. This "overflow" stimulus produces precisely the same results as a stimulus arising in the motor cortex, and it affects the motor nerves which arise from the segment of the spinal medulla in which the "focus of irritation" is situated.

The viscero-motor reflex may be observed in the case of structures innervated through the sympathetic system, and many examples can be brought forward. The board-like contraction of the muscular abdominal wall in cases of acute general peritonitis, the localised contraction of the upper part of the right rectus abdominis in cholecystitis (p. 265), the contraction of the cremaster in renal colic (p. 364), are all instances of this condition.

Particular examples of the viscero-sensory and viscero-motor reflexes are detailed in the sections dealing with the individual viscera (see Stomach, Ureter, Bladder, etc.).

II

THE ORGANS OF SPECIAL SENSE

The organs of special sense include the nose, the ear and the eye.

The Ear, or Organ of Hearing,

consists of three parts, namely—(1) The Auricle and the External Acoustic Meatus, (2) the Cavum Tympani or Middle Ear, and (3) the Internal Ear.

The skin of the **Auricle** receives its nerve-supply from two quite different sources. Its postero-inferior part is supplied from the cervical plexus through the great auricular nerve (C. 2, 3), but its antero-superior part is supplied from the fifth cerebral nerve through the auriculo-temporal branch of the mandibular division (Fig. 40).

The **External Acoustic Meatus** is about 1 inch in length, and is partly cartilaginous and partly osseous. At its medial extremity the meatus is closed by the *tympanic membrane*, which is set obliquely so that its lateral surface is directed forwards and downwards as well as laterally. Examination of the membrane by reflected light is rendered more difficult on account of the bends which occur in the meatus. The cartilaginous portion, which forms the lateral third, passes medially, forwards and upwards; the lateral part of the osseous portion passes medially and backwards, while the rest of the canal is directed medially, forwards and slightly downwards. In order to obtain the best possible view of the membrane, it is necessary to bring the movable cartilaginous

portion into line with the lateral part of the osseous portion, and this can be effected by dragging the auricle upwards and forwards.

In the young child the osseous portion of the meatus is very short and the downward direction of the lateral surface of the membrane is more marked than it is in the adult.

The narrowest part of the meatus is placed at about one-third of an inch from the membrane, and foreign bodies which succeed in passing beyond this point may only be removed with difficulty. The whole of the meatus is covered by a cuticular lining, which is firmly adherent both to the cartilaginous and to the osseous walls, and, on this account, furuncles in the meatus are a source of very acute pain.

The *cerumen*, or ear-wax, is secreted by the modified sweat glands of the cuticular lining and it is normally worked to the exterior by the movements of the mandibular condyle, which lies below and in front of the cartilaginous meatus. If the finger is placed in the external acoustic meatus and the mouth is alternately opened and closed, the effect of the movements of the condyle on the lumen of the meatus can be readily demonstrated.

The cuticular lining of the meatus, which also covers the lateral aspect of the tympanic membrane, is supplied, almost entirely, by branches from the *auriculo-temporal nerve*. The postero-inferior part of the membrane and the adjoining parts of the meatus, however, receive additional supply from the *auricular branch of the vagus* (p. 96). Referred pain in the external acoustic meatus may be due to irritation of any of the terminal branches of the trigeminal nerve, but it is most commonly associated with inflammatory conditions of the teeth of the mandible and consequent stimulation of the inferior alveolar (dental) nerve (p. 75). Similar pain may occur as the result of stimulation of terminal branches of the vagus, but this condition is by no means common. Further, not only may the meatus be the site of referred pain, but pathological conditions in the meatus may give rise to

referred symptoms in the distribution of the trigeminal or of the vagus nerve. In this way a small piece of inspissated ear-wax may be sufficient to set up a "focus of irritation" (p. 195) in the nucleus of the vagus, and so give rise to intractable coughing or chronic dyspepsia.

In syringing the external acoustic meatus for the removal of cerumen, foreign bodies, etc., the nozzle of the instrument should be inserted at the postero-superior quadrant, so that it does not impede the outflow of the fluid employed.

Otoscopic examination will be dealt with when the tympanic membrane is described.

The **Cavum Tympani**, or **Middle Ear**, is an air-space in the interior of the petrous portion of the temporal bone. Anteriorly, it communicates with the naso-pharynx through the *auditory* (*Eustachian*) *tube*, while, posteriorly, it opens into the *tympanic* (*mastoid*) *antrum*. These three structures are all lined with muco-periosteum, which is directly continuous with the mucous membrane lining the pharynx. That part of the middle ear which lies above the upper border of the tympanic membrane is termed the *epitympanic recess* (*attic*).

Suppurative conditions of the middle ear are of frequent occurrence, especially following the exanthemata, and on this account the relations of the cavity are of great importance.

The **roof** of the middle ear is formed by a moderately thin plate of bone, termed the *tegmen tympani*, which separates the cavity from the middle fossa of the skull and the temporal lobe of the brain. Upward spread of septic processes in the middle ear may give rise to meningitis or extra-dural abscess (*i.e.* between the tegmen tympani and the dura mater), or it may lead to the formation of an abscess in the temporal lobe of the brain. (Forty per cent. of all cerebral abscesses occur in the temporal lobe and can be referred to this cause.)

The **floor** of the middle ear is formed by a plate of bone, which separates the cavity from the jugular foramen and the commencement of the internal jugular vein. The latter structure may become the site of a septic thrombosis, if down-

ward spread occurs in the course of a middle ear infection, and the clot may extend along the vein so that it can be felt on palpation at the upper part of the anterior border of the sterno-mastoid.

The **anterior wall** of the middle ear is occupied, in its lateral

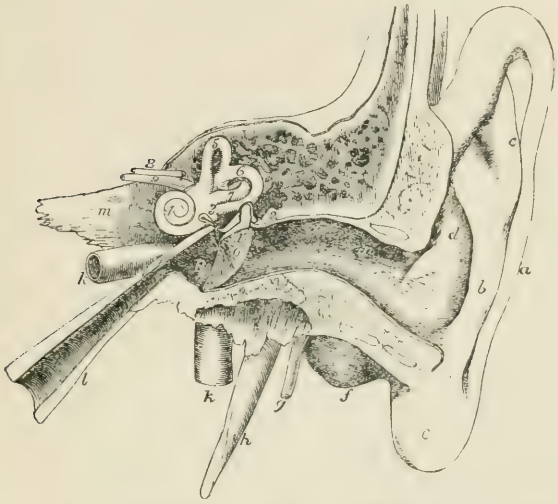


FIG. 77.—Section through the Auricle, the External Acoustic Meatus and the Tympanum. (TURNER'S *Anatomy*.)

a. Helix.	*k*. Internal carotid artery.	*p*. Tympanum.
b. Antitragus.	*l*. Auditory (Eustachian) tube.	1. Malleus.
c. Antihelix.	*m*. Apex of petrous temporal.	2. Incus.
d. Concha.	*n*. External acoustic meatus.	3. Stapes.
e. Lobule.	*o*. Tympanic membrane.	4. Cochlea.
f. Mastoid process.		5, 6, 7. Semicircular canals.
g. Facial nerve.		8. Facial nerve.
h. Styloid process.		9. Acoustic nerve.

part, by the opening of the *auditory* (*Eustachian*) *tube*. The connexion thus established with the naso-pharynx ensures equality in the air pressure on the two sides of the tympanic membrane. Obstruction of the auditory tube, such as occurs in the condition of adenoids (p. 330), is followed by the

gradual absorption of the air in the middle ear, and, as the atmospheric pressure on the outside of the membrane is unopposed, the membrane is bulged medially. Under these circumstances, the conduction of sounds to the internal ear is gravely disturbed. *Artificial inflation* of the middle ear, whether by Valsalva's method or by means of a Eustachian catheter (p. 329), is carried out for the purpose of equalising the pressure on the two sides of the tympanic membrane.

In its medial part, the anterior wall separates the middle ear from the canal which contains the internal carotid artery. Cases have been recorded in which this portion of the wall has become necrosed, following otitis media, and the patient has died from the resulting hæmorrhage.

The **posterior wall** of the middle ear communicates with the *tympanic* (*mastoid*) *antrum* through an opening situated in its upper part. Suppurative processes beginning in either of the two cavities soon spreads to involve the other.

The **lateral wall** of the middle ear is formed by the tympanic membrane and, above its upper border, by a small part of the squamous portion of the temporal bone.

The **Tympanic Membrane** consists of three layers, which form an outer cuticular, a middle fibrous, and an inner mucous stratum. It presents a very intimate relation to the *malleus*, the head of which, however, lies in the epitympanic recess (attic) above the level of the membrane. The handle of the malleus passes downwards and slightly forwards between the fibrous and mucous strata, and its outline can be determined on otoscopic examination. At its upper part, the handle of the malleus is crossed by the chorda tympani nerve (p. 84), which emerges from a small canal in the posterior wall and passes forwards to the anterior border of the membrane, where it enters another canal, which conducts it to join the lingual nerve (p. 75).

On Otoscopic Examination the handle of the malleus can be distinctly seen, and from its lower end, which lies a little below the centre of the membrane, a "cone of light" passes

downwards and forwards over the antero-inferior quadrant of the tympanic membrane (Fig. 78).

Posterior to the handle of the malleus the shadow of the long process of the incus may be made out. It is parallel to the former but lies on a slightly deeper plane, and is not in direct contact with the membrane. As a result, it can only be observed under favourable conditions.

The "cone of light" is taken as a guide when the operation of *paracentesis* is carried out for the evacuation of pus from the middle ear. The incision is made immediately posterior to, and on a level with, the "cone of light," so that it passes

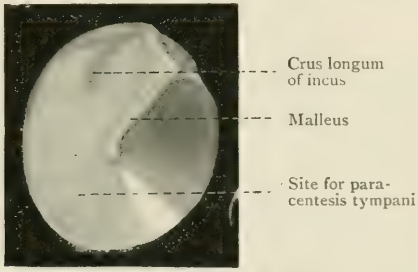


FIG. 78.—Lateral Aspect of Right Tympanic Membrane.

NOTE.—The "cone of light" occupies the antero-inferior quadrant of the membrane.

through the postero-inferior quadrant. This area is chosen, as it is well removed from the ossicles and the chorda tympani. Further, on account of the obliquity of the membrane, good drainage is afforded by an opening in this position.

The **medial wall** of the middle ear is formed by a part of the petrous portion of the temporal bone, and it separates the cavity from the internal ear. Nearly the whole extent of this wall is occupied by a well-marked elevation, termed the *promontory*, which is produced by the first coil of the cochlea. At the postero-superior corner of the promontory, the foot-piece of the stapes fills in an oval aperture in the bone and it is in contact with the perilymph of the internal ear. At the

postero-inferior corner of the promontory, there is a small circular foramen, termed the *fenestra cochleæ* (*rotunda*), which is closed by a membrane. This membrane intervenes between the middle ear and the perilymph of the cochlea (p. 207), and it lies practically opposite to the postero-inferior quadrant of the membrana tympani. As the middle ear is normally rather less than one-eighth of an inch wide at this point, in performing paracentesis care must be taken lest the point of

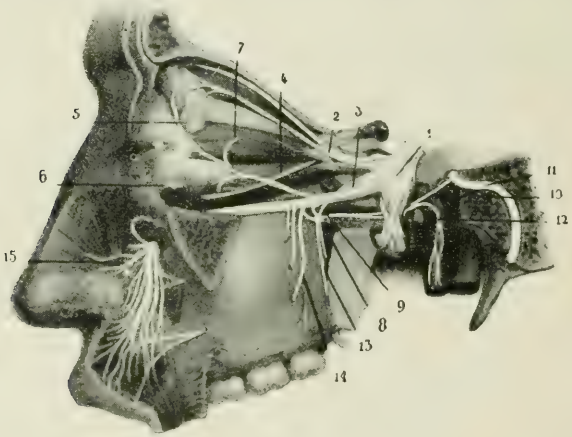


FIG. 79.—The Facial Nerve traversing the Facial Canal in the Petrous Part of the Temporal Bone.

11. Facial nerve.

the instrument pass across the middle ear and open into the labyrinth.

The **facial canal**, which transmits the facial nerve through the petrous portion of the temporal bone, passes backwards above the promontory. As the bony wall which separates it from the cavity of the middle ear is extremely thin, it may readily become necrosed in the course of otitis media, exposing the facial nerve and leading to facial paralysis (p. 87).

Two small *muscles*, termed the *tensor tympani* and the

stapedius, are found in the middle ear. The former occupies a small bony canal, placed just above the auditory (Eustachian) tube, and passes backwards to be inserted into the upper end of the handle of the malleus. As the tensor tympani approaches its insertion, it winds round a small bony process, termed the processus cochleariformis, so that, when it contracts, it draws the handle of the malleus in a medial direction, and thus increases the normal slight concavity on the lateral surface of the tympanic membrane. In this way the membrane is rendered tense. The muscle receives its nerve-supply from the otic ganglion (p. 70), but it is believed that the fibres originate in the nucleus of the facial nerve and are conveyed to the ganglion by the lesser superficial petrosal nerve (p. 92) (Sahli).

The *stapedius* arises within the posterior wall of the middle ear and passes forwards to be inserted into the neck of the stapes. The precise action of the stapedius is somewhat doubtful, but it has been suggested that it is antagonistic to the tensor tympani. On this supposition, it is clear that paralysis of the stapedius will lead to the condition of hyperacousis (p. 80), since the tensor tympani is no longer opposed. The stapedius receives its nerve-supply from a small branch of the facial nerve. This branch arises as the facial nerve descends to reach the stylo-mastoid foramen, and it passes forwards in a minute canal in the posterior wall of the middle ear.

The **Tympanic (Mastoid) Antrum** lies in the posterior part of the petrous portion of the temporal bone. It varies somewhat in size, but it always communicates with the epitympanic recess (attic) of the middle ear through a passage termed the *aditus*, which is placed in the upper part of the anterior wall of the antrum. In addition, it communicates, either directly or indirectly, with the air-cells of the mastoid process, and the whole system is lined by a prolongation of the muco-periosteum of the middle ear.

The **relations** of the antrum are very similar to those of the

tympanic cavity. Its *roof* is formed by the tegmen tympani (p. 200) and its *floor* by the jugular fossa (p. 200). *Anteriorly*, it is related to the middle ear. *Posteriorly*, a thin plate of bone alone separates it from the transverse (lateral) sinus, as the vessel descends in its groove on the mastoid portion of the temporal bone (p. 114). In its *medial wall* the lateral semicircular canal is embedded, while the facial canal turns downwards in the medial wall of the aditus. *Laterally*, the antrum is related to the lateral surface of the skull immediately behind the upper part of the external acoustic meatus. In the infant this wall is only about one-eighth of an inch thick ; by the sixth year, it has increased to a quarter of an inch, and, in adult life, it varies from a half to three-quarters of an inch in thickness.

Suppurative disease in the tympanic (mastoid) antrum is a fertile source of intra-cranial abscess. When the infection spreads in an *upward* direction, the temporal lobe of the brain is involved, but it may spread *backwards*, causing thrombosis of the transverse (lateral) sinus. This vessel receives many tributaries from the cerebellum, and the infection may spread along them, ultimately giving rise to a cerebellar abscess. Spread in a *medial* direction involves the internal ear, and chronic progressive inflammation of the labyrinth (p. 90) is the result.

The **Internal Ear** consists of a complicated, closed, membranous tube, termed the *membranous labyrinth*, which is situated in the *osseous labyrinth*, a large space in the interior of the petrous temporal. The anterior part of the osseous labyrinth is known as the *bony cochlea*, the middle part is termed the *vestibule*, while the posterior part constitutes the *osseous semicircular canals.*

The anterior extremity of the membranous tube is spirally coiled to form the *cochlea*, and the posterior end of the cochlea opens into a small sac which is known as the *saccule.* The posterior extremity of the tube is arranged to form three *semicircular ducts*, set, respectively, in vertical, frontal (coronal),

and horizontal transverse planes. Both extremities of each semicircular canal open into a sac, termed the *utricle* (Fig. 80).

The *ductus endolymphaticus* issues from the saccule and unites with the *ductus utriculo-sacculares* from the utricle. By means of these connections the endolymph circulates freely throughout the whole of the membranous labyrinth.

The saccule, the utricle and their ducts are all placed in the vestibule of the osseous labyrinth.

The membranous labyrinth does not occupy the whole of the available space within the osseous labyrinth, and the interval between it and the bone is filled with a fluid, termed *peri-*

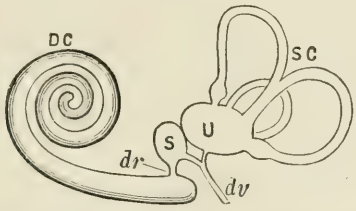


FIG. 80.—Diagram of the Membranous Labyrinth. (TURNER'S *Anatomy*.)

DC. Ductus cochlearis. *SC*. Semicircular ducts. *dr*. Ductus reuniens.
S. Saccule. *U*. Utricle. *dv*. Ductus vestibuli.

lymph. When the foot-piece of the stapes is moved medially, waves are set up in the perilymph, and they pass up the cochlea to its summit and then descend to impinge on the membrane which closes the fenestra cochleæ (rotunda) (p. 204). As the waves pass along, they are transmitted through the wall of the membranous cochlea to the endolymph and so stimulate the processes of the cells which are connected with the terminal fibres of the cochlear division of the acoustic nerve.

The terminal branches of the vestibular division of the acoustic nerve end in and around specialised cells in the walls of the membranous semicircular ducts. They are stimulated by movements in the endolymph, and they are also affected

by conditions which interfere with the tension of the labyrinthine fluid. Menière's disease (p. 90) may be caused by an increase in pressure, possibly owing to over-secretion of endolymph, or it may also be caused by hæmorrhage into the interior of the semicircular ducts. Both of these factors produce their results by direct mechanical stimulation of the terminal branches of the vestibular nerve.

The cochlea is the essential part of the auditory apparatus, while the semicircular ducts are concerned with equilibration.

The Eye

1. The Lacrimal Apparatus.—The **Lacrimal Gland** lies in contact with a depression in the antero-lateral part of the roof of the orbit. Inferiorly, it rests on the eyeball, behind, and on the superior fornix of the conjunctiva, in front, so that when the upper eyelid is everted, the outline of the anterior part of the gland can be made out. It is from the anterior part of the lacrimal gland that its numerous *ducts* pass, and they open directly into the conjunctival sac. The tears are carried downwards and medially across the anterior surface of the eyeball by the movements of the eyelids. The lacrimal secretion forms a thin film over the eyeball, and the surface tension of the fluid maintains the sheet intact.

At the medial end of the border of each eyelid, there is a small papilla, in the centre of which a fine opening, termed the *lacrimal punctum*, leads into the *lacrimal duct.* These ducts carry away the excess of fluid from the medial corner of the conjunctival sac. At first, for about 2 mm., they are directed at right angles to the border of the lids, but they then turn, almost at right angles, and run medially to open into the *lacrimal sac* (Fig. 81).

The Lacrimal Sac is placed in a groove in the anterior part of the medial wall of the orbit. Its upper extremity is blind, and, after being joined by the lacrimal ducts, the sac narrows inferiorly and becomes continuous with the *naso-*

lacrimal duct. This duct lies in a bony canal in the lateral wall of the nose and opens below into the forepart of the inferior meatus of the nose, under cover of the anterior extremity of the inferior concha (turbinated bone). It is only half an inch long and is provided, near its lower end, with a small valve, which prevents the upward passage of air or fluids from the nose to the lacrimal sac.

The *secreto-motor nerves* of the lacrimal gland are derived

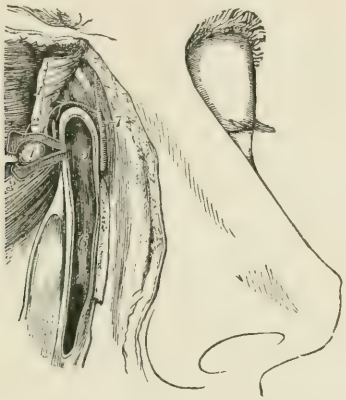


FIG. 81.—The Lacrimal Apparatus. (TURNER'S *Anatomy*.)

1. Orbicularis oculi muscle.
2, 3. Lacrimal canals.
4. Lacrimal caruncle.
5. Lacrimal sac.
6. Naso-lacrimal duct.
7. Angular artery.

from the lacrimal branch of the ophthalmic division of the trigeminal nerve, but they reach the semilunar (Gasserian) ganglion from the sympathetic plexus, which surrounds the internal carotid artery (p. 186). The lacrimal secretion is therefore diminished in paralysis of the ophthalmic nerve and in lesions which involve the cervical sympathetic trunk in any part of its course.

It should be remembered that the gland does not begin to secrete until the second or third month, and that its secretion

is partially or completely inhibited in toxic conditions. It will be found, therefore, that children who are seriously ill rarely shed tears.

The puncta lacrimalia are normally in apposition with the ocular conjunctiva, and only under these conditions can the secretion enter the lacrimal ducts and so drain away through the lacrimal sac and naso-lacrimal duct into the nose. In paralysis of the orbicularis oculi (p. 82), the puncta fall away from the surface of the eye and the lacrimal secretion, being unable to enter the ducts, overflows on to the cheek, constituting the condition of *epiphora*. The same condition will arise if the punctum is too narrow, either congenitally or following inflammatory conditions, or if there is any obstruction in the naso-lacrimal duct.

2. The Eyelids.—The skin of the upper eyelid is supplied by the supra-trochlear, the supra-orbital and the lacrimal nerves (ophthalmic division of V.), while that of the lower eyelid is supplied entirely by the infra-orbital branch of the maxillary division (p. 69). Under the skin lies the orbicularis oculi (palpebrarum) (p. 82) and, at the margins of the eyelids, the unstriated *ciliary bundle* is found. It derives its nerve-supply, not from the facial like the rest of the muscle, but from the sympathetic. Paralysis of these involuntary fibres gives rise to a variety of ptosis which has been termed pseudo-ptosis (p. 189).

A plate of condensed fibrous tissue lies in each lid deep to the fibres of the orbicularis oculi. These are termed the *superior* and *inferior tarsi*, and the former is much the larger of the two. A thin ligamentous sheet extends from the margins of the bony orbital aperture to blend with the tarsi. Though not particularly strong, it is sufficient to influence the course of intra-orbital hæmorrhage, which is guided downwards behind the conjunctiva (Fig. 82).

The deep surfaces of both eyelids are covered by the conjunctival mucous membrane. From the muco-cutaneous junction the *conjunctiva* passes over the lid and it is then

reflected on to the anterior surface of the eyeball. The lines along which this reflection takes place are known as the *fornices* of the conjunctiva. Modified sweat glands open on the margins of the lids just behind the eyelashes. They may become obstructed and inflamed, giving rise to *styes*. The *tarsal* (*Meibomian*) *glands*, which are embedded in the tarsi, form thin reddish streaks, visible when the lid is everted. They open on the margin of the lid and are liable to become obstructed, causing *tarsal cysts*.

3. The Eyeball consists of segments of two spheres, which differ in the size of their diameters, the anterior or corneal segment being much smaller and more sharply curved than the posterior or scleral segment. As a result, entering rays of light undergo a greater amount of refraction than they would if the eyeball were a perfect sphere.

The **ocular conjunctiva** is thin and translucent, so that the white appearance of the fibrous sclerotic coat of the eyeball is rendered visible. It forms a very thin layer over the cornea. *Subconjunctival hæmorrhage* may arise after rupture of the episcleral vessels, and it is then most profuse around the circumference of the cornea ; or, it may be due to the spread of hæmorrhage from the orbit (p. 210). In the latter case, the hæmorrhage is most marked at the periphery of the conjunctiva and it is scanty in the neighbourhood of the cornea.

The **Sclera** covers the posterior five-sixths of the eye. Anteriorly, it becomes continuous with the *cornea*, which covers the remaining sixth. The sclera is composed of strong fibrous tissue and it receives the insertions of the various ocular muscles (p. 57). It is pierced a little below and medial to its posterior pole by the optic nerve (p. 50), and around the point of entrance of the nerve it is pierced by the ciliary nerves and arteries. The anterior ciliary arteries run forwards on the outer surface of the sclera until they almost reach the corneo-scleral junction, and, before they pass through the sclera, they form anastomoses with one another. In this way an *arterial ring* is formed around the corneo-scleral

junction, but it is only visible when the vessels become engorged with blood, and is seen best in scleritis.

The **Cornea** consists mainly of modified fibrous tissue, and it is directly continuous with the sclera. It is perfectly translucent in order that light may pass through it to reach the retina, and it is therefore devoid of blood-vessels. Numerous lymph-spaces lie in the meshes of its fibrous tissue, and the cornea depends for its nutrition on the lymph which they contain. Ulcers of the cornea derive their blood-vessels from the anastomotic ring above referred to, and, after they heal, they are liable to produce small areas of opacity.

The corneal lymph drains away into a circular canal, termed the *sinus venosus scleræ* (*canal of Schlemm*), which lies in the corneo-scleral junction. This canal helps to drain away the aqueous humor from the anterior chamber of the eye (p. 216).

The **Chorioid** is the vascular coat of the eye. It is placed within the sclera, to which it is attached by some pigment-containing connective tissue, but it does not extend quite so far forwards as the corneo-scleral junction. It contains the blood-vessels which supply the various coats of the eye, and it is separated from the retina internally by a translucent basal membrane.

Congenital deficiencies may occur in the chorioid and are usually associated with similar deficiencies in the retina. The condition, which is known as *coloboma*, is commonly found in the lower and medial quadrant of the fundus. Owing to the absence of the retinal and chorioid coats, the sclera is seen over the affected area on ophthalmoscopic examination, and it appears as a clearly outlined patch, pearly-white in colour.

Inflammation of the chorioid causes localised swellings, which lie deep to the retinal blood-vessels (p. 217), and can therefore be distinguished from inflammatory areas in the retina. The presence of chorioiditis in the region of the macula is of great importance, as the pressure and the inflammatory exudation usually give rise to permanent effects, and, on this account, the prognosis should always be very guarded.

Anteriorly, the chorioid becomes continuous with the **Ciliary Body** and the **Iris**. The ciliary body consists of the ciliary muscle and the ciliary processes (Fig. 82). The *ciliary muscle* lies deep to the anterior part of the sclera and consists

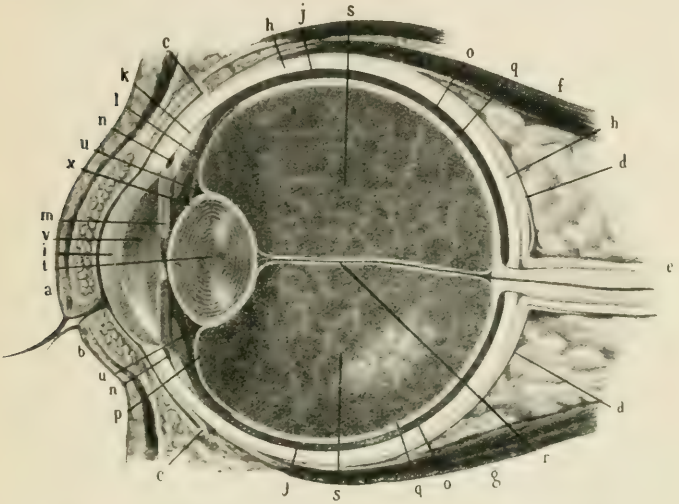


FIG. 82.—Antero-Posterior Median Section through the Eyeball.

a. Upper eyelid.
b. Lower eyelid.
c. Fornix conjunctivæ.
d. Fascia bulbi (of Tenon).
e. Optic nerve.
f. Superior rectus muscle.
g. Inferior rectus muscle.
h. Sclera.
i. Cornea.
j. Chorioid.
k, *l*. Ciliary body.
m. Iris.
n. Spaces of angle of iris (of Fontana).
o. Retina.
p, *q*. Hyaloid membrane.
r. Hyaloid canal (of Stilling).
s. Vitreous humor.
t. Crystalline lens.
u. Zonular spaces (canal of Petit).
v. Anterior chamber.
x. Posterior chamber.

of meridional and circular fibres. The meridional fibres arise from the corneo-scleral junction and radiate backwards and inwards to the ciliary processes and the chorioid. When they contract, they draw the chorioid forwards and so relax the suspensory ligament of the lens (see Lens, p. 215). The circular fibres, which form a ring at the margin of the iris, act

as antagonists of the meridional fibres. The ciliary processes project inwards behind the iris but in front of the crystalline lens.

The **Iris** forms a contractile, perforated diaphragm, which is separated from the posterior aspect of the cornea by the anterior chamber of the eye. Its peripheral border is continuous with the ciliary body and its free, central border bounds the pupil. The iris contains a number of unstriped muscle fibres. Some of these are arranged around the periphery and constitute the *sphincter pupillæ*. They are supplied, through the ciliary ganglion, by the oculo-motor nerve (p. 58) and their action serves to diminish the size of the pupil. Other fibres extend from the periphery towards the free, central margin, constituting the *dilatator pupillæ*. They are supplied, through the ciliary ganglion, by the sympathetic fibres which enter the skull along the internal carotid artery (p. 186). The ultimate origin of these nerves is said to be in the oculo-motor nucleus.

Inflammation of the iris is usually accompanied by severe pain, experienced, for the most part, over the area of distribution of the ophthalmic nerve (Fig. 41). The inflammation may spread to the adjoining ciliary body and chorioid, but the most important complication arises from the formation of adhesions between the posterior surface of the iris and the anterior aspect of the crystalline lens. Such adhesions prevent the fluid in the posterior chamber of the eye from passing forwards into the anterior chamber (p. 216) and an increased intra-ocular tension results, constituting *acute glaucoma*. In order to prevent the occurrence of this complication, mydriatics should be employed at an early stage and, provided that the measure is successful, should be continued until the condition is cured.

The **Retina** forms the innermost coat of the eyeball. Its outer, pigmented layer is continued forwards over the ciliary processes on to the posterior aspect of the iris, but the nervous elements of the retina only extend as far forwards as

the ciliary body. At the point of entrance of the optic nerve, there are no nerve-cells in the retina, which is only represented by an incomplete layer, termed the lamina cribrosa (see Ophthalmoscopic Examination).

The **Vitreous Body**, which occupies the posterior four-fifths of the eyeball, consists of the *vitreous humor* enclosed within a capsule, termed the *hyaloid membrane*. The **Crystalline Lens** lies in a depression on the anterior aspect of the vitreous body, and it is connected to the hyaloid membrane by a *suspensory ligament*, which extends from the membrane beyond the periphery of the lens to the anterior aspect of the lens, where it blends with the capsule (Fig. 82). Circular in shape, the lens possesses a diameter of about 10 mm., while it is 4 mm. in thickness. It consists of concentric laminæ of highly specialised fibrous tissue enclosed within an elastic capsule. When the eye is at rest, the anterior surface of the lens is not so convex as the posterior surface, but, when the meridional fibres of the ciliary muscle contract, the suspensory ligament, which is adherent to the ciliary processes, is drawn forwards and, owing to the elasticity of its substance, the lens becomes more convex on its anterior surface. As age advances, the tissue of the lens becomes denser and loses its elasticity, thus accounting for the condition of *presbyopia*. When the pupil of a presbyopic subject is examined obliquely in reflected light, the appearance is suggestive of cataract, but ophthalmoscopic examination will be sufficient to show that the media are quite translucent.

Congenital malposition of the crystalline lens is a rare abnormality and it is due to failure in development of the suspensory ligament.

The normal lens is perfectly translucent and, therefore, can contain no blood-vessels. During the period of its formation, however, the lens is supplied with blood by a small branch of the ophthalmic artery, which passes forwards from the porus opticus (optic disc) in a small canal in the vitreous body. This artery disappears during the fifth month of intra-uterine

life, but, should it persist, it will give rise to one form of *congenital cataract.* When the lens is in its proper position, its margins cannot be seen on ophthalmoscopic examination, even when the pupil is as widely dilated as possible. The observation of part of its margin shows that the lens is dislocated or partially dislocated. This injury involves complete or partial rupture of the suspensory ligament and, since it has lost its attachments, the lens trembles visibly when the eye is moved—*iridodonesis.*

The **Posterior chamber of the eye** is the small space which intervenes between the peripheral part of the anterior surface of the lens and the posterior aspect of the iris. It contains a clear fluid, termed the *aqueous humor*, which is secreted by the ciliary processes. Through the opening of the pupil the aqueous humor of the posterior chamber communicates with that in the anterior chamber, but, if this communication is prevented by the formation of adhesions between the lens and the iris, the fluid in the posterior chamber accumulates and causes an increase in the intra-ocular tension.

The **Anterior chamber of the eye** is bounded in front by the cornea and behind by the anterior aspects of the iris and the central portion of the lens. In the angle between the peripheral margin of the iris and the cornea, the aqueous humor drains away into the sinus venosus scleræ (canal of Schlemm) (p. 212), and, therefore, cases of glaucoma which are due to obstruction of the normal communication between the anterior and posterior chambers of the eye are readily cured by the performance of iridectomy.

On Ophthalmoscopic Examination, the red reaction of the retina, which is caused by the great vascularity of the chorioid and the corresponding opacity of the sclera, is at once seen. The *Porus Opticus* (*Optic Disc*) can be found by observing on the cornea the image of the lamp, utilised in the examination. By manipulating his mirror, the observer can cause the image to pass along the horizontal diameter of the cornea, and, when the image reaches the junction of the middle

and lateral thirds, the porus opticus comes into view. It consists of an oval, whitish area with an elevated circumference, termed the *papilla of the optic nerve*, and a depressed centre, termed the *excavatio papillæ*. The *arteria centralis retinæ* appears about the centre of the porus opticus and breaks up, in a fairly regular manner, to supply the retina. Large temporal branches pass to the supero-lateral and infero-lateral quadrants, while corresponding branches are distributed to the nasal half of the field. Two smaller branches, the upper and lower macular arteries, pass laterally to the region of the

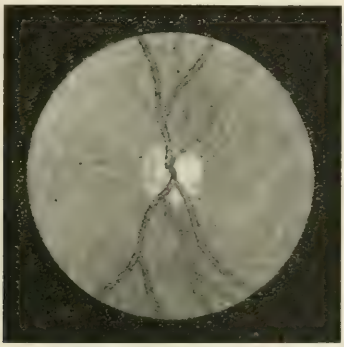


FIG. 83.—The Normal Fundus, showing the Porus Opticus (Optic Disc and the Retinal Blood-vessels. (From SYM'S *Diseases of the Eye.*)

macula lutea. These arteries have corresponding veins, and the latter stand out more clearly on ophthalmoscopic examination owing to their greater lumina and thinner walls. The walls of the retinal veins consist only of a layer of endothelial cells and they are therefore liable to rupture following injury, giving rise to retinal hæmorrhages. No well-marked anastomoses occur between the various branches of the central artery, and they communicate with one another only through the capillary plexuses. On this account, while thrombosis of the main trunk causes complete blindness, thrombosis of any of the larger branches give rise to an area of *scotoma*.

The **macula lutea** is placed at the posterior pole of the eye. It contains a large number of the highly specialised ganglionic cells, since it is the area on which the entering light rays are focused. On this account, too, it is crossed by no blood-vessels, and it depends for its nutrition on transudation from the surrounding areas. It lies slightly above and to the lateral side of the porus opticus.

When the porus opticus (optic disc) is being examined, it must be remembered that the condition of the media—the cornea, the aqueous humor, the crystalline lens and the vitreous body—may greatly affect the field examined. Thus, in *astigmatism*, the outline of the porus opticus is greatly distorted, but it is the cornea and not the porus which is at fault.

Ophthalmoscopic Examination offers a means of examining not only the coats and media of the eyeball, but also the condition of the peripheral circulation and blood-vessels. Important information can be obtained by this means in cases of early arterio-sclerosis. The loss of elasticity in the arterial wall produces in the retina, as elsewhere, tortuosity of the arteries, and, if the veins are examined, it will be found that they are compressed at the points where they are crossed by the thickened arteries, with or without peripheral engorgement, depending on the degree of pressure. The veins are the more readily influenced on account of the thinness of their walls (*vide supra*). Later, the vascular obstruction and the pressure on the lymph-spaces which surround the veins cause œdema of the retina.

The Nose is described on page 325.

III

THE DIGESTIVE SYSTEM

The Teeth

In man and most mammals the teeth which serve during the early years of life are deciduous and disappear before the onset of puberty.

The Deciduous Teeth begin to erupt between the sixth and the ninth months, but their appearance may be considerably delayed in constitutional diseases, of which rickets is by far the most common. The teeth of the mandible usually appear slightly earlier than those of the maxilla, but corresponding teeth on the two sides should erupt at practically the same time. The first teeth to appear are the **central incisors**, and they are soon followed by the **lateral incisors**. The **first molars** erupt early in the second year, and the interval between the first molar and the lateral incisor is filled up by the eruption of the **canine**, about the eighteenth month. The appearance of the **second molar** at the end of the second or the beginning of the third year completes the deciduous set. As the teeth make their way through the mucous membrane of the gums, they may, by stimulation of the sensory branches of the trigeminal nerve, give rise to reflex disturbances, which vary from slight malaise to severe convulsive fits.

The Permanent Teeth begin to erupt during the sixth year, and the first to appear is the **first molar** tooth, which comes to the surface of the gum behind the second deciduous molar. As a result of this arrangement, the child is able to

masticate its food satisfactorily while the deciduous molars are being shed. The **medial** and **lateral incisors** appear during the seventh and eighth years respectively, and are followed by the **first** and **second premolars**, which erupt during the ninth and tenth years. The premolars cannot appear above the gum until the deciduous molars have been removed or have dropped out. The interval between the first premolar and the lateral incisor is filled by the **canine**, which has usually erupted by the end of the twelfth year. The **second permanent molar** varies somewhat in its time of appearance, and it is not unusual for its eruption to be delayed till the fifteenth or sixteenth year. A similar variation is found in the date of eruption of the **third molar** tooth, which completes the permanent set. It may appear at any time between the seventeenth and the thirtieth years.

The roots of the molar and of the premolar teeth lie in relation to the floor of the maxillary sinus (antrum of Highmore), and, when it is necessary to drain the sinus, access can be obtained by removing one of these teeth, preferably a premolar.

Failure of a tooth to erupt is never caused by failure to develop. It may remain embedded in the bone or, if a maxillary tooth, it may be found in the hard palate. This condition may affect any of the teeth, but it is found most frequently in connexion with the third permanent molar. Such a misplaced tooth may give rise to very pronounced reflex symptoms, of which acute neuralgia in the area of distribution of the fifth nerve is the most common.

In cases where congenital syphilis is suspected, the condition of the teeth may offer valuable evidence. In congenital syphilis the incisors are short and peg-shaped, and their cutting edges are definitely notched,—**Hutchinson's Teeth**. The notching is not natural, for, on eruption, the teeth are normal in appearance. The adamant (enamel) is very thin and soon becomes broken off, leaving the dentine exposed and causing the characteristic notches. It is only when the upper central

incisors are affected in this way that a positive diagnosis of congenital syphilitic affection of the teeth may be made.

Additional incisors and rudimentary fourth molars are occasionally met with, but they are of special interest only to the comparative anatomist.

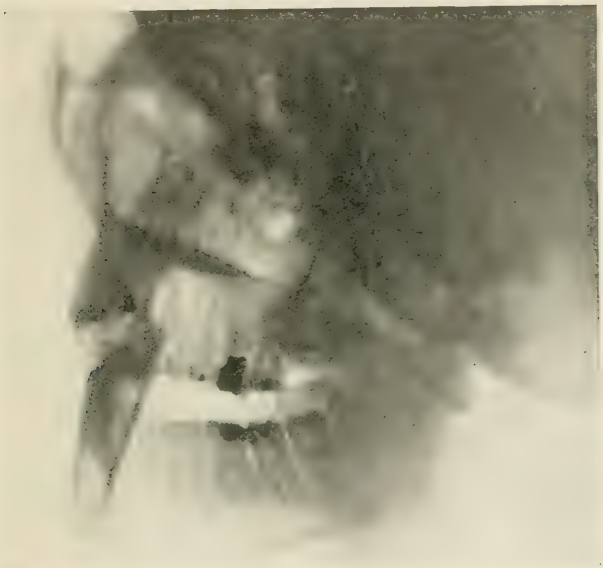


FIG. 84.—Radiogram of Anterior Portion of Head, showing non-eruption of the third upper molar tooth of the right side. The outline of the tooth can be seen embedded in the maxilla. (From a Radiograph by CHAS. A. CLARK, Esq., L.D.S.Eng.)

The *nerve-supply* of the teeth is derived from the trigeminal nerve. The maxillary nerve supplies the teeth of the maxilla and the mandibular nerve those of the mandible.

The *lymph vessels* of the maxillary teeth terminate in the submaxillary lymph glands, which are closely related to the submaxillary salivary gland; those from the molar teeth are

also connected with the anterior auricular lymph glands, which lie superficial to the parotid. The lymph vessels of the mandibular teeth also join the submaxillary lymph glands, but some pass directly to the upper anterior group of the deep cervical glands. These glands are associated with the upper part of the internal jugular vein.

The Salivary Glands

The **Parotid** is the largest of the three chief salivary glands. It lies in a somewhat wedge-shaped recess, which is bounded posteriorly by the anterior border of the sterno-mastoid, anteriorly by the posterior border of the ramus and the condyle of the mandible, and superiorly by the floor of the external acoustic meatus. The anterior part of the gland passes forwards into the face, overlapping the masseter muscle, and is termed the *facial process* (Fig. 85).

The **parotid duct** emerges from the facial process and, after passing forwards across the masseter, it turns medially to pierce the buccinator muscle. It then passes forwards for a short distance in the submucous tissue of the cheek and pierces the mucous membrane opposite the second molar tooth of the maxilla. Its orifice is sometimes marked by a small papilla, which may be felt with the tip of the tongue. The *course* of the duct corresponds, on the surface, to the middle third of a line drawn from the lower border of the external acoustic meatus to a point midway between the red margin of the upper lip and the ala of the nose.

As the openings in the buccinator and in the mucous membrane through which the duct passes are not placed opposite one another, a valve-like arrangement is provided to prevent the backward passage of air or fluid. Despite this arrangement, the duct occasionally becomes greatly inflated and forms a distinct tumour in the cheek. The condition occurs most commonly in glass-blowers, who have to exercise considerable expulsive force in the performance of their craft.

The parotid gland is surrounded by a strong *sheath*, continuous with the deep cervical fascia, and, on this account, its enlargement in inflammatory conditions is somewhat restricted. The facial nerve, after emerging from the stylo-mastoid foramen (p. 80), enters the substance of the gland and breaks up into its terminal branches in that situation. It may occasionally be compressed in acute parotitis, owing to œdema of the gland

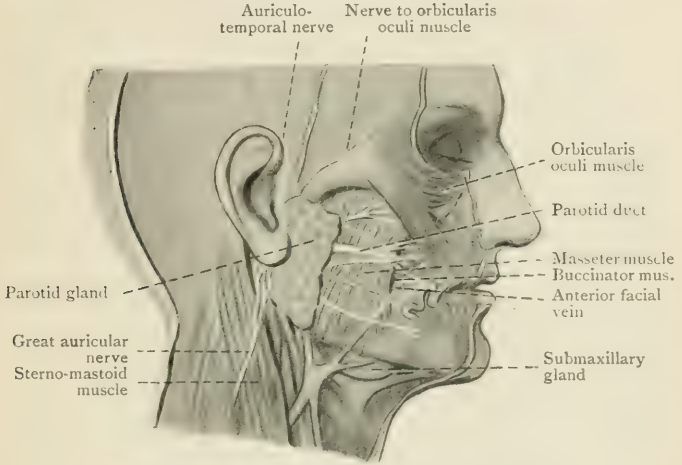


FIG. 85.—The Parotid Gland and its Duct.

within its unyielding sheath, and temporary facial paralysis may result.

If the tip of the finger is placed in front of the tragus of the external ear, it will be found to sink into a depression when the mouth is opened. This depression is produced by the forward movement of the mandibular condyle and it contains a small part of the parotid gland, which may become enlarged in acute parotitis. Under these circumstances, the movements of opening and closing the mouth give rise to considerable pain, and are therefore very much restricted.

Since the cartilaginous external acoustic meatus lies in a

groove on the superior aspect of the parotid, it may be compressed when the gland is enlarged. This condition may give rise not only to painful symptoms but also to a slight degree of deafness.

A small portion of the facial process is occasionally quite separate from the rest of the gland. It lies immediately above the duct and is termed the **accessory parotid** (**socia parotidis**). In acute parotitis it forms a discrete little swelling in the cheek, and may then be mistaken for an inflamed lymph gland.

The *lymph vessels* of the gland pass to the anterior auricular (p. 222) and the parotid lymph glands, and thence to the deep cervical lymph glands.

The **Submaxillary Salivary Gland** lies under cover of the posterior part of the body of the mandible and is situated above the level of the hyoid bone. The main part of the gland is superficial and is in contact with the deep cervical fascia. Its *duct* passes forwards and upwards and opens through the mucous membrane of the floor of the mouth. Its orifice is placed on the summit of a small papilla, which is situated close to the frenulum of the tongue.

The **Sublingual Gland** lies under cover of the anterior part of the body of the mandible and is more deeply placed than the submaxillary gland, since it is separated from the deep cervical fascia by the mylo-hyoid muscle (p. 72). Its superior border is in contact with the mucous membrane of the anterior part of the floor of the mouth and forms a slight bulge, which may be recognised with the tip of the tongue. The bulging is rendered more prominent if the finger is insinuated under the body of the mandible opposite the canine tooth and is thrust upwards.

When the mouth is opened and the tip of the tongue is elevated, a fold of mucous membrane is seen in the lateral part of the floor of the mouth. This fold is termed the *plica sublingualis* and it indicates the position of the sublingual gland. It is pierced by the *sublingual ducts*, which vary in number from 8 to 20.

The **salivary secretion** contains an amylolytic enzyme, termed *ptyalin*, which is capable of acting on cooked starchy foods. At birth only the secretion of the parotid gland contains ptyalin, but, although the enzyme appears in the submaxillary and sublingual secretions during the third month, its amylolytic action is not completely developed until the end of the first year. The amylolytic action of the pancreatic secretion is similarly delayed, and hence it follows that but little starchy food should be given to children until they are a year old.

Calcium salts are present in the saliva, more especially in the secretion of the submaxillary gland. The latter fact accounts for the deposition of tartar on the mandibular teeth and for the occurrence of submaxillary calculi.

The *nervous mechanism* of the salivary secretion is referred to on page 189.

The Mouth.—The mucous membrane of the cheeks, gums, lips and floor of the mouth is entirely supplied by the trigeminal nerve. Reference has already been made to the results of anæsthesia of the cheeks and lips (p. 75) and to the similar results of paralysis of the buccinator (p. 84), which constitutes the chief muscular stratum of the cheek.

The mucous membrane of the gums is firmly adherent to the periosteum, and consequently the accumulation of pus under the mucous membrane is associated with severe local pain.

The *lymph vessels of the gums* do not all follow the same course. Those from the inner surface of the maxillary gums pass to the upper and anterior group of the deep cervical lymph glands (p. 222), while those from their outer surface terminate in the submaxillary lymph glands (p. 221). The lymph vessels from the anterior part of the outer surface of the mandibular gums follow the lymph vessels from the central part of the lower lip and end in the submental lymph glands, which lie on the mylo-hyoid muscles, immediately below the chin; all the remaining lymph vessels from the mandibular gums join the submaxillary group.

The **Tongue** consists of a muscular mass, partially covered by mucous membrane. Its anterior part lies almost horizontally in the floor of the mouth, while its posterior part lies almost vertically in the anterior wall of the oral part of the pharynx (Fig. 86). The junction of the anterior two-thirds with the posterior third of the tongue is marked in the median plane by a small depression, termed the *foramen cæcum*, which possesses considerable morphological interest (p. 411). Immediately in front of the foramen cæcum, the vallate papillæ are arranged in a V-shaped manner on the dorsum of the tongue.

Collections of lymphoid tissue, termed the *lingual tonsil*, are situated under the mucous membrane of the pharyngeal portion of the tongue. They are of interest because they are very constantly enlarged in cases of status lymphaticus.

The *sensory nerve-supply* of the tongue is derived from the lingual and the glosso-pharyngeal nerves (pp. 75 and 92), while the muscles of the tongue are supplied by the hypoglossal nerve (p. 107).

The *lymph vessels* from the tip of the tongue join the submental glands (p. 225); those from the borders and substance of the tongue pass to the submaxillary lymph glands (p. 221) and thence to the upper anterior group of the deep cervical glands; those from the base of the tongue pass directly to the latter group.

The **Isthmus Faucium** forms the communication between the mouth and the oral part of the pharynx. It is bounded, above, by the soft palate: below, by the tongue: and, on each side, by the glosso-palatine arch (anterior pillar of the fauces), which extends from the lateral part of the lower surface of the soft palate to the side of the tongue.

The **Oral Part of the Pharynx** lies behind the isthmus faucium. Above, it communicates freely with the naso-pharynx, but this communication is completely shut off when the soft palate is elevated.

A fold of mucous membrane, termed the pharyngo-palatine arch (posterior pillar of the fauces), extends downwards on the

lateral wall from the lateral extremity of the free posterior border of the soft palate. A triangular interval is enclosed

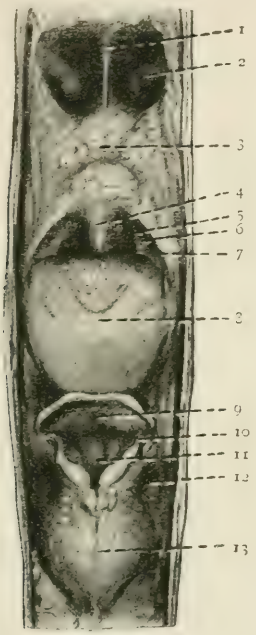


FIG. 86.—The Interior of the Pharynx, viewed from behind, after removal of the posterior pharyngeal wall.

1. Nasal septum.
2. Inferior concha (turbinated bone).
3. Soft palate.
4. Uvula.
5. Glosso-palatine arch (anterior pillar of fauces).
6. Tonsil.
7. Pharyngo-palatine arch (posterior pillar of fauces).
8. Dorsum of tongue.
9. Epiglottis.
10. Ary-epiglottic fold.
11. Upper aperture of larynx.
12. Recessus piriformis.
13. Posterior aspect of cricoid cartilage.

between the pharyngo-palatine and the glosso-palatine arches (pillars of the fauces) and it contains the *palatine tonsil*, a structure of great importance during childhood.

The **palatine tonsil** is formed by the outgrowth of numerous little diverticula from the pharyngeal wall. These diverticula become surrounded by a mass of lymphoid tissue, which rapidly increases in amount and bulges the mucous membrane inwards. An ill-defined capsule of fibrous tissue covers the tonsil on its lateral aspect. The original diverticula remain patent and form the tonsillar *crypts*, which become filled with a caseous exudate in follicular tonsillitis. The crypts of the tonsil provide access to many varieties of micro-organisms, of which the tubercle bacillus is much the commonest. During the early years of life, the lymphoid tissue of the palatine tonsils may hypertrophy to such an extent that they almost meet in the middle line, and this condition is usually accompanied by a similar hypertrophy of the pharyngeal tonsil (p. 329). The respiratory difficulties caused by this enlargement may be so great that the contour of the chest is greatly altered, pigeon-chest, Harrison's sulcus and other deformities being induced.

The *lymph vessels* of the palatine tonsil pass to one of the upper deep cervical glands, placed in close relation with the internal jugular vein at the level of the greater cornu of the hyoid bone. From this lymph gland efferents pass to the lower group, some of which are intimately related to the cervical dome of the pleura. It has been suggested (p. 352) that tuberculous infection of the palatine tonsil may, through the medium of the lymph glands and vessels, be responsible for the production of apical phthisis. Other efferents descend into the thorax and establish connexions with the bronchial glands. In this way another route is opened up for the passage of tuberculous infection from the palatine tonsil to the lung.

The posterior wall of the oral part of the pharynx is a common site of *angio-neurotic œdema*, a circumstance which is accounted for by the laxity of the submucous tissue in this situation.

The muscular wall of the pharynx is entirely deficient

anteriorly, on account of the presence of the choanæ (posterior nares), the isthmus faucium, and the laryngeal aperture (Fig. 86). It is formed posteriorly and on each side by the constrictor muscles, which become continuous below with the muscular coat of the œsophagus. These muscles play an important part in the act of deglutition, and they are assisted by the muscles of the tongue and soft palate.

The **act of deglutition** comprises a voluntary and an involuntary stage, but the two overlap one another and are difficult to distinguish. The mouth is closed by certain of the muscles of mastication (p. 70), and the cheeks and lips are pressed against the teeth and gums by the contraction of the buccinators and the orbicularis oris. The soft palate is raised and drawn tense so as to cut off the communication between the nasal and the oral parts of the pharynx. The tongue and hyoid bone are suddenly drawn upwards by the mylo-hyoids, digastrics, etc., and the bolus of food is forced backwards through the isthmus faucium. As it enters the oral part of the pharynx, its passage is hastened by the approximation of the palatine arches (pillars of the fauces), which squeeze it onwards. The bolus is then acted on by the constrictors, which force it downwards into the œsophagus.

Owing to the attachments of the thyreo-hyoid membrane (Fig. 121), the elevation of the hyoid bone is necessarily accompanied by elevation of the larynx, and, at the same time, the ary-epiglottic folds (p. 332) become shortened and approximated so that the apices of the arytænoids are brought into contact with the tubercle (cushion) of the epiglottis. In this way the cavity of the larynx is almost completely shut off from the pharynx. As a result, the breath is held during deglutition, and anything which may cause a sudden inspiration re-opens the communication so that a portion of the bolus may be drawn into the larynx.

Not only does the act of deglutition demand a number of intimately related and complicated movements, but it also brings into action several different groups of muscles, which

are innervated by different cerebral nerves. The fifth nerve is involved in closing the mouth; the seventh, in compressing the lips and cheeks; the ninth, in elevating the larynx; the tenth and eleventh, in elevating the soft palate, in closing the larynx, in approximating the palatine arches and in urging the bolus onwards to the œsophagus; the twelfth, in elevating the tongue. Paralysis of any one of the nerves involved causes an appreciable disturbance only when the lesion is bilateral, and the act of deglutition is interfered with most in lesions of the ninth, tenth and eleventh nerves (Bulbar Paralysis, p. 108).

The **Œsophagus** is a muscular tube which begins in the neck at the level of the cricoid cartilage — sixth cervical vertebra—where it is continuous with the laryngeal part of the pharynx. It passes down through the thorax, pierces the diaphragm and terminates in the abdomen by becoming continuous with the stomach.

In the neck, the œsophagus lies in front of the vertebral column, and, when it is obstructed or compressed against the bone in this region, swallowing becomes impossible, the food being rejected at once. Anteriorly, it is related to the trachea and the recurrent nerves (Fig. 50), while it is overlapped by the posterior borders of the lobes of the thyreoid gland. In the lower part of the neck, the thoracic duct is related to its left border. Enlargement of the thyreoid gland may cause dysphagia secondarily to dyspnœa (Fig. 50), but the condition is rarely met with in practice.

In the thorax, the œsophagus continues its course downwards in front of the vertebral column. In the upper part, it is placed behind the trachea and is crossed by the arch of the aorta (Fig. 113) and the left bronchus. In the lower part of the thorax, the œsophagus deviates slightly to the left and, as it passes through the diaphragm, it lies one inch from the median plane. As it descends, it lies behind the pericardial sac, and as a result of this relationship, swallowing causes pain in the presence of pericarditis (p. 289).

The œsophageal opening is placed in the muscular part of

the diaphragm, and the fibres which surround it have a sphincteric action.

In the abdomen, the œsophagus bends to the left to join the cardiac end of the stomach. This part of the tube is only half an inch in length, but, partly owing to the bend which it makes to the left and partly owing to the sphincteric action of the œsophageal opening in the diaphragm, it may hinder the operation of gastroscopy by obstructing the passage of the instrument.

Œsophageal Obstruction.—The thoracic portion of the œsophagus may be compressed by aneurisms of the aortic arch (p. 319), by mediastinal tumours, originating either in the thymus or in the lymph glands, or by abscesses in connexion with the upper thoracic vertebræ. Such abscesses cause obstruction by compressing the œsophagus against the unyielding aorta and left bronchus.

Malignant stricture affects the œsophagus at the three points where it normally shows a slight degree of constriction. These occur—(1) At the commencement of the tube, or 6 inches from the incisor teeth; (2) at the point where the œsophagus is crossed by the left bronchus, or 10 inches from the incisor teeth; and (3) at the distal end of the tube, or 15 inches from the incisor teeth. Œsophageal bougies should be graduated in such a way that the operator can locate the site of the stricture. Before such an instrument is passed, the possibility that the obstruction is due to an aneurism of the aortic arch must be carefully excluded. It should also be remembered that a carcinomatous stricture may be very friable, and it is then readily perforated by a bougie. A little difficulty is often experienced in guiding the instrument past the prominent upper border of the lamina (posterior arch) of the cricoid cartilage, and care must be taken not to diagnose a stricture at this point without sufficient evidence.

In all muscular tubes the stage of hypertrophy on the proximal side of an obstruction is followed, sooner or later, by a stage of dilatation. On this account, when the site of an œsophageal obstruction is placed low down in the thorax,

food is retained for some time before it is ejected, and there may be some doubt as to whether or not it has been within the stomach. The mucous membrane of the œsophagus contains numerous mucous glands, and, consequently, ejecta from the œsophagus are alkaline in reaction and are mixed with mucus. In all doubtful cases, the diagnosis can be made clear by examination with the fluorescent screen during the passage of a bismuth meal.

In order to examine the œsophagus with X-rays, the patient is placed obliquely with reference to the screen, so that the shadow of the bismuth may be seen satisfactorily, as it passes down in front of the vertebral column and behind the pericardium.

The *arteries* of the œsophagus are derived, in the neck, from the inferior thyreoids: in the thorax, from the descending thoracic aorta: in the abdomen, from the left gastric (coronary) artery. They anastomose freely with one another, and similar communications exist between the *veins*, which join the vena azygos in the thorax and the left gastric vein in the abdomen. In this way the systemic and portal circulations are connected with one another, and, in portal obstruction, this venous anastomosis may become greatly enlarged in the lax submucous tissue of the œsophagus. The rupture of varicose veins in this situation gives rise to hæmatemesis, which may be the first sign of cirrhosis of the liver (p. 274).

The *nerves* of the œsophagus are derived from both vagi, which form a plexus on its walls in the thorax (p. 100). This plexus is reinforced by fibres from the sympathetic trunks, and their centres in the spinal medulla are situated in the upper thoracic segments. Pain referred from the œsophagus is usually experienced over the lower part of the sternum, in the areas supplied by the terminal branches of the fourth and fifth intercostal nerves. It is most marked when violent peristaltic movements affect the circular muscular fibres on the proximal side of an obstruction.

Regions of the Abdomen.—Before the anatomy of the abdominal part of the alimentary canal is described, it is necessary to consider the plan adopted for the subdivision of the abdominal cavity into certain arbitrary regions. The following imaginary planes are utilised for the purpose.

The **subcostal plane** passes horizontally through the body on a level with the most dependent parts of the tenth costal cartilages. Posteriorly, it cuts the vertebral column near the

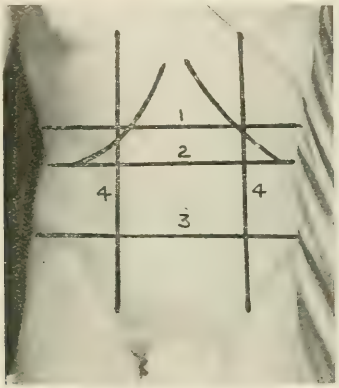


FIG. 87.—Anterior Aspect of Trunk, showing the planes utilised for the surface topography of the abdominal viscera.

1. Transpyloric plane.
2. Subcostal plane.
3. Intertubercular plane.
4. Right and left lateral planes.

upper border of the third lumbar vertebra. The **intertubercular plane**, which is parallel to the subcostal plane, passes through the tubercles on the iliac crests and cuts the vertebral column near the upper border of the fifth lumbar vertebra. These two horizontal planes are intersected at right angles by two sagittal planes, which pass through the mid-points of the two clavicles; they are known as the **right** and **left lateral planes** (Fig. 87).

By these four planes the abdominal cavity is divided into nine regions, and the lines along which the planes cut the surface of the anterior abdominal wall may be utilised in

referring the individual viscera to the surface of the body. The three regions which occupy the median plane are termed from above downwards, the *epigastric*, the *umbilical* and the *hypogastric regions* respectively.

The **transpyloric plane**, though not utilised in the subdivision of the abdominal cavity, is extremely useful in connexion with the relations of viscera to the surface. It passes horizontally through the body and bisects the line which joins the upper border of the manubrium sterni to the pubic symphysis. As a rule, it cuts the vertebral column opposite the lower border of the first lumbar vertebra and lies about 1½ inches above the subcostal plane.

These regions and planes will be frequently referred to in the description of the various abdominal viscera.

The Peritoneum

The **Peritoneum** is the most extensive serous membrane in the body. In the male, it forms a completely closed sac, but, in the female, the peritoneal cavity communicates with the uterine (Fallopian) tube—and so indirectly with the exterior—through the ostium abdominale (p. 396).

It is customary, as in the case of the pleura (p. 341), to refer to *visceral* and *parietal layers*, but it must be remembered that certain viscera, *e.g.* the pancreas, kidneys, etc., are retroperitoneal, and that they are partially covered on their anterior surfaces by the peritoneum of the posterior abdominal wall. The arrangement of the peritoneum in relation to the abdominal viscera is best comprehended by the study of sagittal and transverse sections through the abdominal cavity.

A *sagittal section in the median plane* passes, successively, through the liver, the stomach, the transverse colon and coils of the small intestine (Fig. 88), and, on the posterior abdominal wall, it passes through the pancreas and the third part of the duodenum. When the cut surface of such a section is examined (Fig. 88), it is found that the layer of peritoneum on

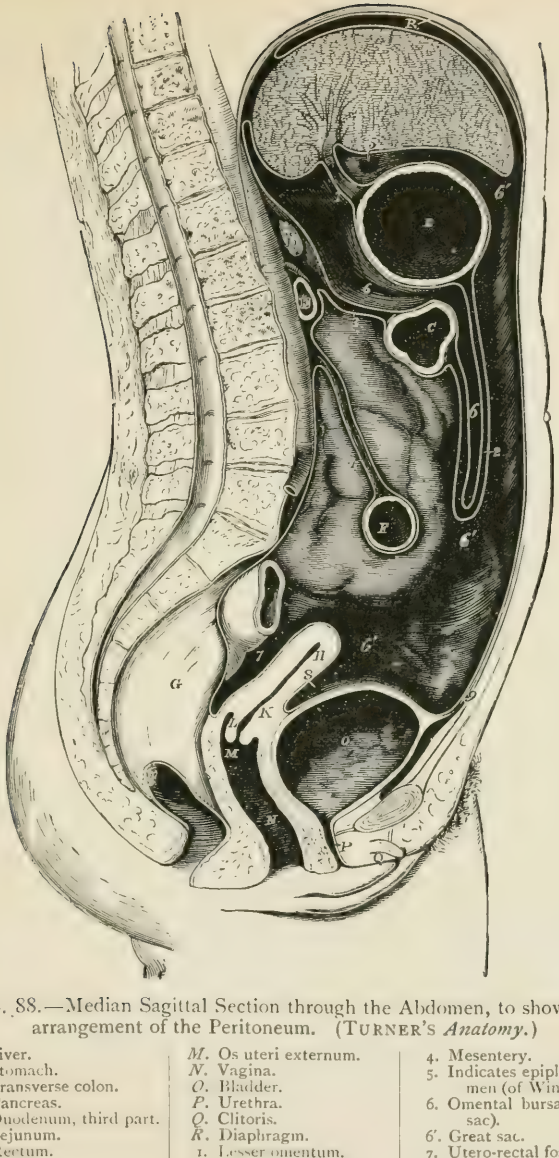


FIG. 88.—Median Sagittal Section through the Abdomen, to show the arrangement of the Peritoneum. (TURNER'S *Anatomy*.)

A. Liver.
B. Stomach.
C. Transverse colon.
D. Pancreas.
E. Duodenum, third part.
F. Jejunum.
G. Rectum.
H. Uterus.
K. Cervix uteri.
L. Vaginal part of cervix.
M. Os uteri externum.
N. Vagina.
O. Bladder.
P. Urethra.
Q. Clitoris.
R. Diaphragm.
1. Lesser omentum.
2. Greater omentum.
3. Transverse mesocolon.
4. Mesentery.
5. Indicates epiploic foramen (of Winslow).
6. Omental bursa (lesser sac).
6'. Great sac.
7. Utero-rectal fossa.
8. Utero-vesical fossa.
9. Parietal layer of peritoneum.

the deep surface of the anterior abdominal wall extends upwards on to the inferior surface of the diaphragm, from which it is reflected on to the liver. It covers the superior and anterior surfaces and it extends on the inferior surface as far back as the porta hepatis (transverse fissure of the liver). There it comes into contact with a layer of peritoneum which is passing forwards on the inferior surface of the liver, and the two layers descend in contact with one another to the lesser curvature of

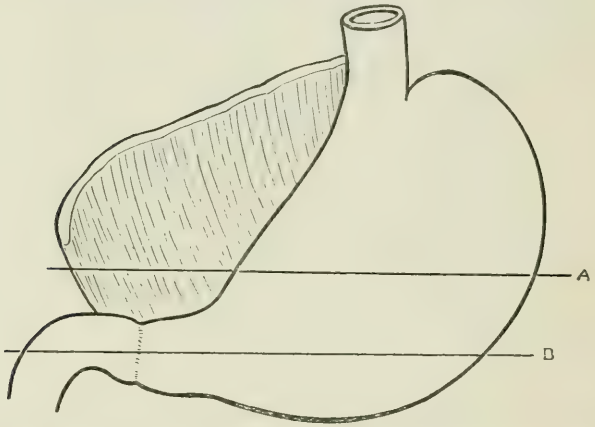


FIG. 89.—Diagram of the Stomach and the Lesser Omentum, to show the lines along which the stomach is cut in Fig. 90, A, and in Fig. 91, B.

the stomach. This fold, which connects the stomach to the liver, is termed the **lesser (gastro-hepatic) omentum**, and, when it is examined on surface view (Fig. 89), it is found to possess a free border at its right extremity.

The two layers of the lesser omentum enclose the stomach, constituting its serous coat, and then descend from the greater curvature to form the **greater omentum**, which varies considerably in its downward extent. Inferiorly, the two peritoneal layers are carried upwards again on a more posterior plane till they meet and enclose the transverse colon. From the colon

the two layers pass upwards and backwards to reach the anterior border of the pancreas, where they finally diverge from one another.

In Fig. 88 the lower part of the greater omentum is seen to consist of four layers, but in the adult these layers are generally fused to one another, and the anterior two layers, as they pass in front of the transverse colon, are commonly adherent to the gut. The short upper part of the greater omentum which intervenes between the greater curvature of the stomach and the transverse colon is termed the **gastro-colic ligament.**

The fold which attaches the transverse colon to the inferior border of the pancreas is known as the **transverse mesocolon.** Its upper layer ascends over the posterior abdominal wall and is ultimately reflected on to the liver. It subsequently forms the posterior layer of the lesser omentum. The lower layer of the transverse mesocolon descends from the pancreas, and, after plastering the duodenum against the posterior abdominal wall, it is drawn off the wall to form the **mesentery,** which suspends the coils of the jejunum and ileum within the peritoneal cavity.

It will be seen from Fig. 88 that a part of the peritoneal cavity is shut off behind the stomach. This portion is termed the **omental bursa (lesser sac)**; it forms a sac which is completely closed except at one point, where it communicates with the rest of the peritoneal cavity (great sac). The communication lies behind the right free border of the lesser omentum and is termed the **epiploic foramen (of Winslow).**

Sagittal sections demonstrate the structures which constitute the anterior and posterior walls of the omental bursa. The anterior wall is formed, from above downwards, by the liver, the lesser omentum, the posterior surface of the stomach and the gastro-colic ligament. The posterior wall is formed, from below upwards, by the transverse colon, the transverse mesocolon, the anterior surface of the pancreas and the viscera on the posterior abdominal wall.

The left and right lateral boundaries can only be studied in

transverse sections through the abdomen. In Fig. 90 a transverse section has been made so as to pass through the epiploic foramen, and the level of this section is represented on the surface of the stomach in Fig. 89. The great sac becomes continuous with the omental bursa behind the right free border of the lesser omentum, which therefore constitutes the anterior boundary of the epiploic foramen, and it may be observed that the *bile duct*, the *hepatic artery* and *portal vein* are placed

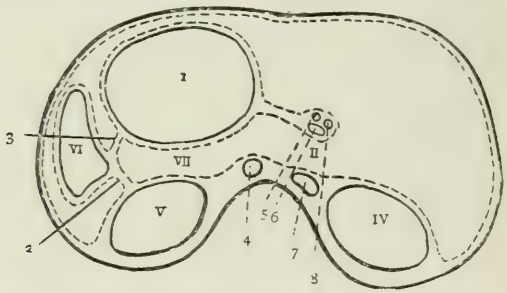


FIG. 90.—Transverse Section through the Abdomen at the level of the epiploic foramen (of Winslow), to show the disposition of the peritoneum.

In this section the stomach is cut along the line A (Fig. 89).

I. Stomach.
II. Epiploic foramen.
IV. Right kidney.
V. Left kidney.
VI. Spleen.
VII. Omental bursa (lesser sac).
2. Lieno-renal ligament.
3. Gastro-splenic ligament.
4. Aorta.
5. Hepatic artery.
6. Portal vein.
7. Inferior vena cava.
8. Bile duct.

between the two layers of the lesser omentum at its right border. The inferior vena cava, as it ascends through the abdomen, lies behind the peritoneum on the posterior wall of the epiploic foramen, which separates it from the portal vein at this level (Fig. 90).

When the two layers of peritoneum which enclose the stomach are traced to the left, they pass from the fundus to the spleen, forming the **gastro-splenic ligament** (Fig. 90), and the left layer of this fold is continued over the gastric, dia-

phragmatic and renal surfaces of the spleen. From the spleen, the two layers are continued backwards to the anterior surface of the left kidney, where they finally diverge from one another. It will be seen that the omental bursa, which lies behind the stomach, is bounded on the left side by the gastro-splenic ligament, the hilus of the spleen and the **lieno-renal ligament**.

If a section is made through the abdomen immediately below the epiploic foramen (Fig. 89, B), the omental bursa

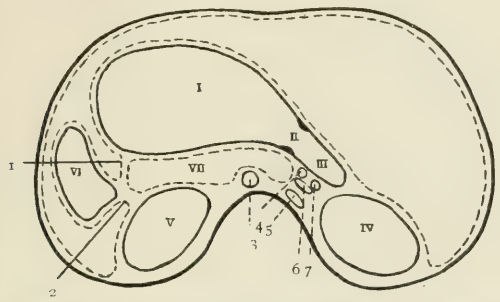


FIG. 91.—Transverse Section through the Abdomen, below the level of the epiploic foramen (of Winslow).

The section cuts the stomach along the line B in Fig. 89.

I. Stomach.
II. Pylorus.
III. Duodenum.
IV. Right kidney.
V. Left kidney.
VI. Spleen.
VII. Omental bursa (lesser sac).
1. Gastro-splenic ligament.
2. Lieno-renal ligament.
3. Aorta.
4. Gastro-duodenal artery.
5. Inferior vena cava.
6. Portal vein.
7. Bile duct.

is seen as a completely closed sac. The peritoneum on the posterior surface of the stomach (Fig. 91) covers the posterior aspect of the pylorus and is continued for a short distance over the posterior surface of the first part of the duodenum. It then becomes reflected on to the posterior abdominal wall, and this reflection forms the upper part of the right lateral boundary of the omental bursa. When Figs. 90 and 91 are compared with one another, it will be found that the two layers of peritoneum which separate the inferior vena cava from the

portal vein and bile-duct in Fig. 90 have disappeared in Fig. 91, so that these structures become much more intimately related to one another.

The jejunum and ileum are suspended within the peritoneal cavity by the **mesentery**. This fold possesses an oblique attachment to the posterior abdominal wall, extending from the left side of the second lumbar vertebra, downwards and to the right, into the right iliac fossa, and it permits a wide range of movement to the gut. The blood-vessels, nerves and lymph vessels pass to and from the intestine between its two layers, and the mesenteric lymph glands occupy a similar position. When the glands are enlarged and tuberculous, they throw definite shadows in radiograms, and they can be recognised by the irregularity of their disposition and by the fact that their distribution is quite different in radiograms taken at different times.

The peritoneal cavity shows a natural subdivision into smaller parts. The **supra-colic compartment** lies above and in front of the greater omentum, the stomach, the lesser omentum and the liver (Fig. 88), and it communicates with the omental bursa (lesser sac). The **infra-colic compartment** lies below and behind the greater omentum, the transverse colon and the transverse mesocolon, and it is further subdivided into *right* and *left* parts by the mesentery. The **pelvis** constitutes the lowest compartment of the peritoneal cavity. These compartments are not completely separated from one another, but inflammatory conditions tend, as a rule, to be localised to the compartment in which they originate.

The peritoneum is a large lymph-sac and it contains lymph which normally transudes from the abdominal blood-vessels. The parietal peritoneum possesses *stomata*, which serve to drain away the lymph, and these stomata are most numerous on the inferior aspect of the diaphragm. In cases of peritonitis, it is important therefore to prevent septic material from reaching the inferior aspect of the diaphragm, and this

may be effected by keeping the patient in the semi-sitting posture or by raising the head of the bed.

When the transudation from the abdominal veins is excessive, the stomata are unable to carry away all the fluid, and the condition of **ascites** is brought about. It may result from any pathological state which retards the outflow of blood from the portal vein or from the inferior vena cava. Thus it may be due to cardiac lesions (p. 316), cirrhosis of the liver (p. 274), or abdominal tumours.

When fluid is present in the peritoneal cavity, it obeys the law of gravitation, unless it is limited by adhesions. If the examination is conducted with the patient in the dorsal decubitus, it will be found that the lateral regions of the abdomen are dull to percussion, whereas the areas near the median plane are tympanitic. If, however, the patient turns over on to his right side, it will be found that the left lateral region has become tympanitic, whereas the dulness is confined to the right half of the body. This alteration is partly due to gravitation and partly to the fact that the hollow viscera float on the upper surface of the ascitic fluid.

Paracentesis Abdominis.—This operation may be carried out by means of Southey's tubes or by means of a simple trochar and cannula. It is of great importance to ascertain that the patient's bladder is empty (p. 367) before paracentesis abdominis is performed. The patient is placed in a sitting or semi-sitting posture, because, in that position, the fluid to be drawn off is brought into contact with the lower part of the anterior abdominal wall and the intestines, which float on its upper surface, are removed from risk of injury. The upper limit of the fluid is determined by percussion and the trochar is inserted, after due attention to asepsis, through the linea alba into the dull area. The fluid should be allowed to drain away slowly and the alteration of the intra-abdominal pressure, caused by its removal, may be compensated for by the gradual tightening of an adjustable abdominal bandage.

Nerve-supply of the Peritoneum.—For many years

clinicians have taught that, although the visceral peritoneum is insensitive to stimuli which produce painful impressions when applied to the skin, the parietal peritoneum is a highly sensitive membrane. Mackenzie believes that the parietal peritoneum is in no way different from the visceral layer, and that the pain which is apparently referable to the parietal peritoneum is in reality due to stimulation of the numerous sensory nerve-endings which abound in the extra-peritoneal fat.

Little is known with regard to the particular segments of the spinal medulla which innervate the peritoneum, but it is probable that they are identical with the segments which innervate the abdominal wall. Abnormal stimulation of the nerves supplying the peritoneum gives rise to both viscero-sensory and viscero-motor reflexes (p. 192). This condition is well shown when stomach contents escape into the peritoneal cavity following the perforation of a gastric ulcer. Pain is referred to the whole of the anterior abdominal wall, and the muscles of the wall, which are innervated by the same nerves, become contracted and board-like.

The Stomach

The **Stomach** is situated chiefly in the left hypochondriac and the epigastric regions, but it also descends for a variable distance below the subcostal plane (p. 233). At its proximal end, or **cardiac orifice**, which lies immediately below the diaphragm, 1 inch to the left of the median plane, the stomach becomes continuous with the œsophagus; at its distal end or **pylorus**, which lies at a lower level and slightly to the right of the median plane, it becomes continuous with the duodenum. The stomach possesses anterior and posterior surfaces, which are separated from one another by two borders, termed the lesser and greater curvatures. To the left side of the cardiac orifice, the stomach bulges upwards into the left cupola of the diaphragm, and this dilatation is referred to as the **fundus**.

The **pyloric canal,** which leads to the pylorus, is the narrowest portion of the stomach.

The *anterior surface* of the stomach lies in the posterior wall of the supra-colic compartment of the peritoneal cavity, and is therefore related to the great sac (Fig. 88). This area lies in contact with (1) the left lobe of the liver, (2) the left half of the diaphragm, and (3) the anterior abdominal wall. The hepatic area consists of a strip along the lesser curvature, while the diaphragmatic area consists of the fundus and adjoining portion. The diaphragm separates this part of the stomach from the apex of the heart, the base of the left lung and the pleura. Great distension of the stomach may act mechanically upon the heart, causing palpitation and cardiac irregularity, and, in debilitated bed-ridden patients, it may cause some collapse of the lower lobe of the left lung by direct pressure.

It is impossible to state accurately the size of a normal stomach, since it is constantly undergoing changes of shape which depend upon its physiological condition at the time of examination. When the patient is lying on his back, the positions of the cardiac orifice and the pylorus can be determined with sufficient accuracy for practical purposes. The cardiac orifice is placed behind the seventh left costal cartilage, 1 inch from the sternum, while the pylorus is situated on the transpyloric plane (p. 234), about half an inch to the right of the median plane. A line joining the right side of the cardiac orifice to the upper border of the pylorus, drawn with a slight downward convexity, represents the lesser curvature (Fig. 92). The greater curvature begins at the left side of the cardiac orifice and passes upwards and to the left, reaching its highest point on the fifth rib. It then passes downwards and to the left as far as the anterior axillary line. The rest of the greater curvature passes to the right with a gentle downward convexity, and finally ascends rather sharply to join the lower border of the pylorus (Fig. 92).

A tympanitic stomach note is obtained on percussion over

those parts of the stomach which lie in relation to the anterior abdominal wall and to the lower limit of the left pleural sac. Superiorly, the note becomes resonant to light percussion as soon as the lower border of the lung is reached. To the right side, the tympanitic gastric area is bounded by the liver dulness, and, to the left side, by the splenic dulness. Inferiorly, the greater curvature of the stomach is closely related to the trans-

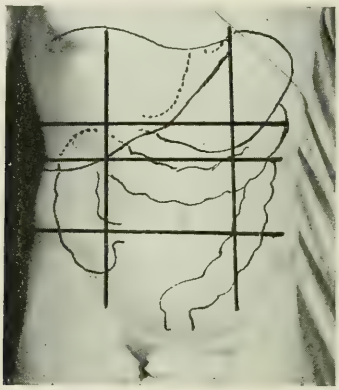


FIG. 92.—Anterior Aspect of the Trunk, showing the surface relations of the liver, the stomach and the large intestine.

NOTE.—The reference lines are the same as those shown in Fig. 87.

verse colon, which yields a tympanitic note of a somewhat different quality on percussion (Pl. II.).

The area on the costal parietes of the left side which yields a tympanitic gastric note to percussion under normal conditions is termed **Traube's Space**. From the description which has been given of the boundaries of this area, it will be clear that hepatic enlargement encroaches on the space from the right side, and that splenic enlargement encroaches on it from the left side. When the upper border of the space is found to be lower than normal, and formed by an area of absolute dulness, the condition is due to an effusion into the left pleural sac.

The *posterior surface* of the stomach forms part of the anterior wall of the omental bursa (Fig. 88), which intervenes between the viscus and its "bed." When an ulcer on this surface of the stomach becomes perforated, the omental bursa

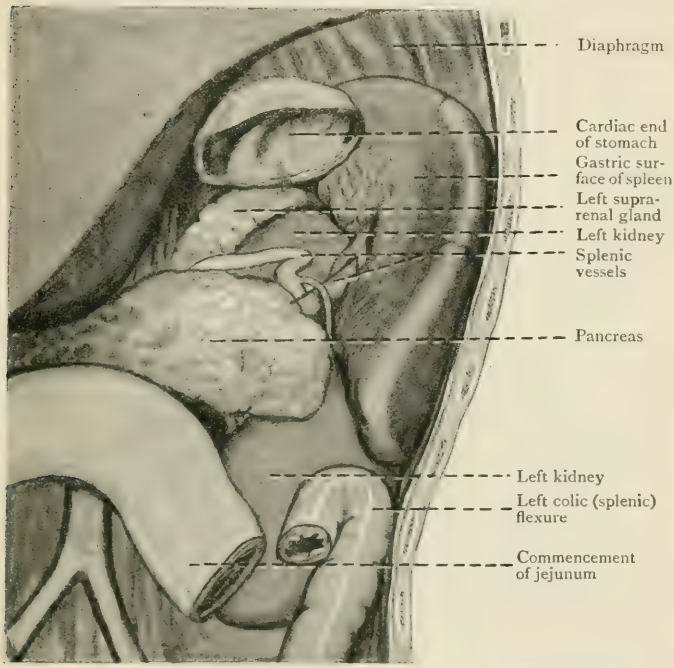


FIG. 93.—The relations of the Left Kidney and the Viscera which form the "bed" of the Stomach.

is infected. If the ulcer is situated near the pylorus, the epiploic foramen (of Winslow) may be closed by adhesions, and the infection is therefore prevented from spreading to the greater sac. The *stomach-bed* forms a shelving ledge over which the stomach may slip up or down, according to the

position of the body. Above, it is formed by the gastric surface of the spleen, the anterior surfaces of the left kidney and supra-renal gland, and the posterior abdominal wall. Below, it is formed by the anterior surface of the pancreas, the transverse mesocolon and the transverse colon (Fig. 88). The stomach may become adherent to any of these viscera in the presence of a gastric ulcer, and death has been recorded in several cases from hæmorrhage due to erosion of the

FIG. 94.—Normal Tonic Stomach. Radiograph taken in upright position. (From KNOX'S *Radiography*.)

splenic artery, which runs along the upper border of the pancreas (Fig. 93).

Radiographic Examination of the Stomach.—The peritoneal folds which anchor it to the neighbouring viscera permit the stomach to alter its position under the action of gravity. This fact has been clearly demonstrated by the examination of the organ with X-rays, after the patient has been given a bismuth meal. Under examination with the fluorescent screen, the outline of the stomach is very indistinct when the patient is

lying on his back, but it becomes quite evident when the vertical position is adopted. The stomach becomes tubular and assumes a J-shape. The long limb of the J is vertical and lies entirely to the left of the median plane, its lower limit often reaching the fibro-cartilage (intervertebral disc) between the fourth and fifth lumbar vertebræ. The short limb of the J passes upwards and to the right and terminates at the pylorus, which descends to the level of the second or third

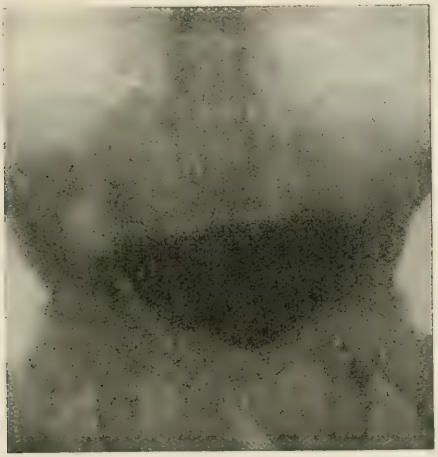


FIG. 95.—Atonic, dilated, Stomach. Radiograph taken in upright position. (From KNOX'S *Radiography*.)

lumbar vertebra in the erect attitude. In a healthy stomach, in which the tonus of the muscular wall is good, it will be found that the upper level of the bismuth is maintained at a higher level in the long limb than it is in the short limb, and that the fundus, since it contains a certain amount of gas (Fig. 94), is outlined as a clear semicircular area on the top of the long limb.

Marked variations from the typical description indicate the existence of pathological conditions. Thus, in radiograms

taken with the patient in the erect posture, the presence of the pylorus at the level of the first lumbar vertebra indicates that it is prevented from descending by pathological adhesions, and suggests the possibility of ulceration in the pyloric region. It may be found that, although the stomach at first assumes a typical J-shape, after a time its shape becomes very indefinite, and, as the two limbs disappear, the bismuth which they contain descends to the same horizontal level (Fig. 95). This appearance indicates a loss of tone in the muscular wall of the stomach, for, although at first able to support a higher column of bismuth in the long limb of the J, the muscle tonus soon becomes fatigued and gives way.

The **Gastric Secretion** is intended to act mainly on proteids. Its most important constituents are *pepsin* and *hydrochloric acid*, and it should be observed that pepsin can carry out its proteolytic action only in an acid medium. Consequently when pepsin is administered in gastric disorders, it should be combined with an acid solution. Some of the hydrochloric acid is required to neutralise the alkalinity of the saliva which is swallowed with the food, while some of it combines with the proteins of the food. As a result, the amount of free hydrochloric acid is very small and is no real indication of the amount secreted.

In addition, the gastric mucosa secretes an enzyme, termed *rennin*, which has a special curdling action on milk. It acts on the casein, which is the principal proteid in milk, and converts it into an insoluble solid. This solid substance is apparently more readily acted on by pepsin than the soluble casein. It may be pointed out that if the milk is lacking in lime salts the action of the enzyme is seriously interfered with.

Lactic acid may be present in gastric contents, but it is a product of carbohydrate decomposition and is not secreted by the gastric mucosa.

In children the hydrochloric acid is relatively less in amount than it is in the adult, and consequently the gastric juice is not so strongly germicidal.

The *capacity* of the stomach in the new-born is only $1\frac{1}{5}$ oz. At three months, it has increased to $4\frac{1}{2}$ oz., at six months to 6 oz., while at the end of the first year it can retain 9 oz. Thereafter it goes on increasing gradually until, in the adult, the average capacity is about 40 oz. or 1 quart.

The **Lymph Vessels** of the stomach pass, by several routes, to terminate in the cœliac lymph glands, which are closely related to the commencement of the abdominal aorta. Before reaching the cœliac glands, the gastric lymph vessels pass through subsidiary groups, including—(1) glands in relation to the pylorus, which also receive afferents from the liver; and (2) glands lying along the upper border of the pancreas, which also receive afferents from the spleen and the pancreas.

In malignant disease of the stomach, secondary growths are frequently found in the liver. They also occur in the pancreas and, more rarely, in the spleen. Occasionally the lower group of the deep cervical glands of the left side may be affected. In this case the infection is carried by the thoracic duct (p. 324), which, at its lower end, receives the efferents from the cœliac lymph glands.

Nerve-supply of the Stomach.—The stomach derives its nerve-supply from two sources, namely,—(*a*) the **sympathetic** and (*b*) the **vagi**.

(*a*) At an early period of development the stomach is simply a localised dilatation of the primitive foregut, and, at this period, it receives its nerve-supply. The proximal or cardiac end of the tube, therefore, is supplied from a higher segment of the spinal medulla than the pyloric end. These nerves have their centres in the fifth, sixth, seventh and eighth thoracic segments, and they pass by the white rami communicantes to the thoracic part of the sympathetic trunk. They descend in the greater splanchnic nerves (p. 187) to the cœliac ganglia and thence are carried on the coats of the gastric blood-vessels to the stomach.

Viscero-sensory and viscero-motor reflexes (p. 192) occur with great frequency in pathological conditions of the stomach,

and Mackenzie has pointed out that it may be possible to diagnose the site of a gastric ulcer from the position of the areas of cutaneous hyperalgesia, when such are present.

Gastric referred pain is experienced in the skin areas supplied by the fifth to the eighth thoracic nerves. As a rule the anterior terminal branches of the anterior rami (primary divisions) of these nerves are affected, and the pain is consequently referred to the epigastric region, but, at the same time, pain may be experienced over the wide areas of distribution of the lateral branches of the intercostal nerves of the left side.

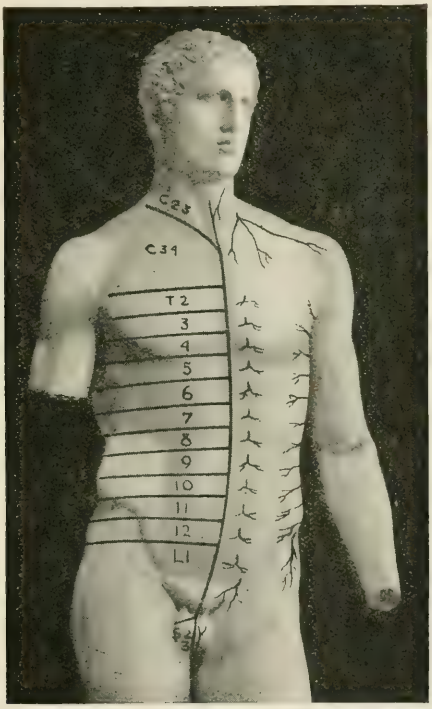
When a "focus of irritation" (p. 195) is established in the spinal medulla as the result of a gastric lesion, areas of cutaneous or muscular hyperalgesia may be found on careful examination. In most cases they occur over the upper part of the left rectus abdominis muscle, but they should also be sought for over the left sacro-spinalis (erector spinæ).

An area of cutaneous hyperalgesia, caused by an *ulcer near the cardiac end of the stomach*, will, theoretically, be situated in the region supplied by the fifth thoracic nerve. On the other hand, a similar area, caused by an *ulcer near the pylorus*, will be found in the region supplied by the eighth thoracic nerve (Fig. 96), *i.e.* the lower part of the epigastric region. *Ulcers affecting the body of the stomach* will give rise to areas of cutaneous hyperalgesia situated in the region supplied by the sixth and seventh thoracic nerves.

Gastric lesions may give rise also to the viscero-motor reflex (p. 197), and, since the viscero-sensory reflex is usually limited to the areas supplied by the anterior terminal branches of the fifth to the eighth intercostal nerves, it is not surprising to find that the viscero-motor reflex is usually limited to the upper part of the left rectus abdominis, which is supplied by the same nerves. When the lateral branches of these nerves are affected, localised contractions may be found in the upper part of the external oblique muscle, and, when the posterior

rami (primary divisions) are involved, similar areas may be found in the sacro-spinalis (erector spinæ).

(*b*) The two vagus nerves enter the abdomen through the œsophageal opening in the diaphragm and break up to form



[*Photo by Alinari.*

FIG. 96.—The Nerve-supply of the Anterior Aspect of the Trunk.

plexuses on both surfaces of the stomach. Some small twigs from these plexuses pass to the liver and the small intestine.

Afferent impulses from the stomach may pass through the sympathetic to the spinal medulla or they may be carried by the vagi to the medulla oblongata. When a lesion of the

stomach is present, a "focus of irritation" (p. 195) may be established in the medulla oblongata as well as in the spinal medulla. On the ingestion of food afferent impulses ascend to the medulla oblongata, and the resulting response probably governs the gastric peristalsis. If a "focus of irritation" is present in the medulla oblongata, these normal afferent stimuli become exaggerated as they ascend to the cortex and they cause an exaggerated response, *e.g.*, emesis. It may be noted that such a focus may be caused by a lesion in any part of the stomach, and that, on this account, the rapidity with which emesis follows the ingestion of food merely indicates the presence of a "focus of irritation" and is no guide to the site of the lesion.

Abnormal afferent impulses from the gastric branches of the vagus may "overflow" in the medulla oblongata and affect the neighbouring nerve-cells. This "overflow" stimulus may affect the cells which exert a depressor influence on the heart, and in this way, without any cardiac lesion, bradycardia may be associated with lesions of the stomach. Similarly, the irritable, uncontrollable cough which sometimes accompanies gastric disturbances is caused by the exaggeration of normal afferent impulses from the larynx, as they pass through a "focus of irritation" in the medulla oblongata.

At the same time it must be remembered that, just as gastric lesions may give rise to disturbances in other viscera either by "overflow" of impulses in the medulla oblongata or by the establishment of a "focus of irritation" in the spinal medulla, so the stomach may be affected reflexly in lesions of other viscera innervated by the vagi. Thus, stimulation of the auricular branch of the vagus in the external acoustic meatus may give rise to symptoms of serious gastric disorder (p. 96); a severe fit of coughing may culminate in vomiting; affections of the biliary passages may lead to the vomiting of food as soon as it is ingested. In the latter case, however, it is doubtful whether we have to deal with a pure vagus reflex or with a sympathetic reflex.

The Small Intestine

The **Duodenum** begins at the pylorus on the right side of the body of the first lumbar vertebra and terminates at the duodeno-jejunal flexure on the left side of the second lumbar vertebra. Between these two points, it forms a **C**-shaped bend, which encloses the head of the pancreas.

The **first part** of the duodenum passes backwards, upwards and to the right in relation to the gall-bladder and the inferior surface of the liver. It lies in front of the bile-duct, portal vein, inferior vena cava and gastro-duodenal artery, and, although its terminal portion is covered by peritoneum only anteriorly, its commencement is covered both anteriorly and posteriorly. This latter fact accounts for the descent of the pylorus when the erect attitude is adopted. In radiograms, after the bismuth meal has passed through the pyloric canal, the commencement of the duodenum throws a shadow, which lies immediately above the pylorus (Fig. 94).

Duodenal ulcers are usually situated on the antero-lateral wall of the first part of the duodenum. A small area in this situation is very constantly supplied by a special branch from the hepatic artery, and it has been suggested that this vessel is an end-artery and that the area in question is therefore not so richly supplied with blood as the rest of the duodenum. An ulcer in the posterior wall of this part of the duodenum may cause death from hæmorrhage by eroding the gastro-duodenal artery (Fig. 91).

The **second part** of the duodenum runs downwards in front of the hilum of the right kidney and extends to the lower border of the third lumbar vertebra. A little below its middle it is crossed by the transverse colon, and so its upper part lies in the supra-colic compartment, while its lower part is on the posterior wall of the right infra-colic compartment. The second part of the duodenum receives the secretions of the liver and the pancreas (pp. 262 and 269).

The **third part** of the duodenum passes to the left and, after

crossing the median plane, ascends till it reaches the left side of the body of the second lumbar vertebra, where it bends downwards and forwards, forming the **duodeno-jejunal flexure**. It

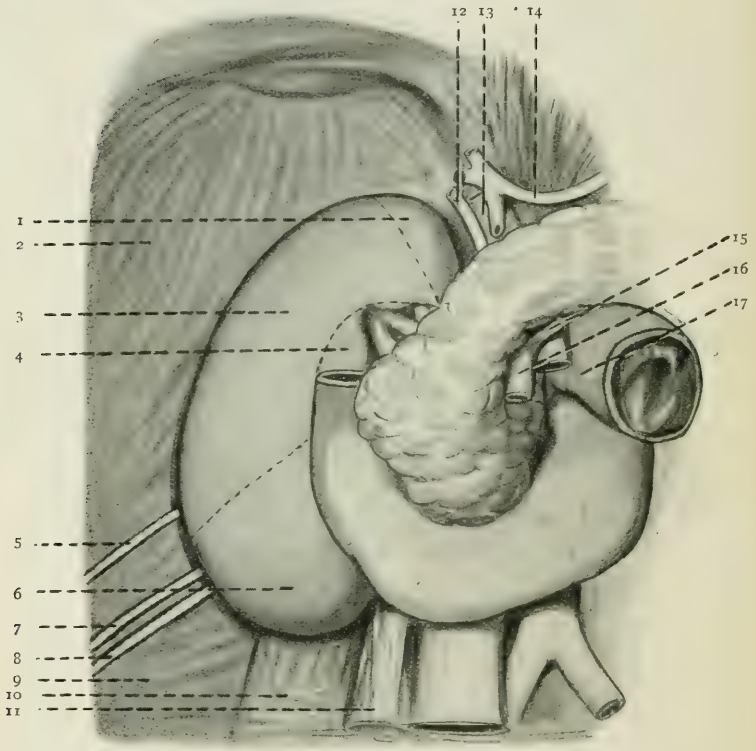


FIG. 97.—The relations of the Right Kidney, the Duodenum and the Head of the Pancreas.

The stomach, the first part of the duodenum, the lesser and greater omenta, the liver and the large intestine have all been removed.

2. Diaphragm.
11. Psoas major muscle.
12. Bile duct.
13. Portal vein.
14. Hepatic artery.
15. Splenic vein.
16. Superior mesenteric vein.
17. Duodeno-jejunal flexure.

crosses in front of the inferior vena cava and the abdominal aorta, and it is itself crossed anteriorly by the superior mesenteric vessels and the root of the mesentery.

With the patient in the dorsal decubitus the duodenum may be mapped out on the surface with a tolerable amount of accuracy, for, since for the most part it is retro-peritoneal, its position undergoes little variation. From the pylorus (p. 243), the first part passes upwards and to the right for a distance of from $1\frac{1}{2}$ to 2 inches. The second part descends medial to the right lateral plane to the level of the umbilicus. The third part passes to the left, below and parallel to the subcostal plane (p. 233), and, on the left side of the median plane, it ascends to the duodeno-jejunal flexure. The latter point lies $\frac{1}{2}$ inch below the transpyloric plane (p. 234) and about 1 inch to the left of the median plane (Fig. 124).

The *nerves* which supply the duodenum are carried on the walls of its arteries. These are derived from two sources, namely, the cœliac artery and the superior mesenteric, and the nerves which they convey belong partly to the group of sympathetic nerves which supplies the stomach and partly to the group which supplies the jejunum. The centres for these nerves in the spinal medulla lie in the lower thoracic region (T. 8 and 9) and overlap the centres for the stomach and the jejunum. On this account the referred pain which is experienced in *duodenal ulcer* cannot be distinguished from the referred pain caused by a gastric ulcer in the pyloric region, and the pain initiated by violent peristaltic movements of the duodenum in *chronic intestinal stasis* (p. 257) is in every way similar to the pain experienced in violent peristalsis of the jejunum.

Some of the terminal branches of the vagi assist the sympathetic nerves to supply the duodenum.

The **Jejunum and Ileum** constitute the freely movable part of the small intestine, and they are attached to the posterior abdominal wall by a continuous dorsal mesentery, which begins above on the left side of the second lumbar vertebra and, extending downwards and to the right, ends

below in the right iliac fossa. This mesentery contains the blood-vessels, nerves and lymph-vessels of the intestine and a large number of lymph glands. The latter commonly become enlarged in *tabes mesenterica* and throw recognisable shadows in radiograms. It is characteristic of them that they are irregularly placed and that, owing to the mobility of the mesentery, they occupy different positions in radiograms taken at different times.

Taken together, the jejunum and ileum form a tube about 20 feet in length, but the two parts are not clearly marked off from one another. In the jejunum, the mucous membrane is thrown into numerous transverse folds which are termed the **plicæ circulares** (**valvulæ conniventes**). They serve to increase the size of the absorptive area without unduly increasing the length of the intestine. The plicæ circulares decrease in number in the lower part of the jejunum, and they are almost absent in the lower part of the ileum.

In the ileum, collections of lymphoid tissue, termed the **intestinal tonsils** (**Peyer's patches**), form elongated oval areas in the mucous membrane. They are especially well marked in the terminal part of the ileum and in the cæcum. In *typhoid fever* these areas are the site of small circular ulcers, the confluence of which may form a typical ovoid patch, corresponding in outline to the shape of the area. In *tuberculous disease* the intestinal tonsils may be the site of chronic ulceration. In this condition the ulcer tends to spread in the direction of the intestinal blood- and lymph-vessels, *i.e.* at right angles to the long axis of the gut, and when such an ulcer heals the accompanying cicatricial changes result in the formation of annular strictures.

Under certain conditions (p. 277), the terminal portion of the ileum may become kinked in such a way as to cause serious obstruction to the passage of the intestinal contents. As a result of this obstruction, the small intestine becomes abnormally distended and the weight of the gut drags the duodeno-jejunal flexure, which is fixed in position, in a down-

ward direction. A secondary kinking, therefore, is brought about at the termination of the duodenum, which, in turn, becomes abnormally distended and reacts on the stomach. The absorption of toxic material from the loaded bowel gives rise to serious symptoms, and the condition has been termed **chronic intestinal stasis**.

When no obstruction is present in the small intestine, a bismuth meal should reach the cæcum within five hours.

The **Lymph Vessels** of the small intestine terminate in the mesenteric glands (p. 256), which send efferents to join the lymph glands associated with the abdominal aorta.

The Nerve-supply of the Small Intestine is derived from sympathetic fibres which have their centres in the lower thoracic segments of the spinal medulla. In addition, the duodenum and the first coils of the jejunum probably receive some of the terminal branches of the vagi.

Referred pain in connexion with the small intestine is usually experienced in the umbilical region (Fig. 96), but, owing to the great length of the gut, the presence of areas of cutaneous hyperalgesia is not of the same diagnostic value as it may be in gastric disturbances.

The *mucous membrane* of the small intestine secretes the **succus entericus**, which takes an active part in the digestion of carbohydrates. It contains enzymes which convert di-saccharids into monosaccharids, rendering them ready to be absorbed by the blood-vessels in the wall of the gut.

In addition, the succus entericus contains a substance, termed *secretin*, which normally stimulates the flow of the pancreatic secretion (p. 270). Further, the succus entericus affects proteid metabolism by converting the inactive trypsinogen of the pancreas into trypsin, which has a powerful proteolytic action.

The Liver

The **Liver** occupies practically the whole of the right hypochondriac region and the upper part of the epigastrium, and

in addition it encroaches to a slight extent upon the right lumbar and the left hypochondriac regions (Fig. 92).

The **superior surface** of the liver is in relation to the inferior surface of the diaphragm, which separates it from the right lung and pleural sac, the pericardium, and, to a much lesser extent, from the left lung and pleural sac. Collections of fluid in the right pleural sac or in the pericardium, or enlargement of the right side of the heart (p. 297), may exert a downward pressure on the liver and cause it to project below the right costal margin for some distance.

A similar downward displacement of the liver may be caused by an *intra-peritoneal subphrenic abscess*, situated in the recess of the greater peritoneal sac which extends upwards and backwards between the upper surface of the liver and the inferior surface of the diaphragm (Fig. 88). When the right lobe of the liver is the site of a *tropical abscess*, this peritoneal recess may become obliterated by adhesions. As a result, if the abscess burrows through the upper surface of the liver, it will, in time, perforate the diaphragm and burst into the right pleural sac or even into the lung itself. The latter complication can only occur when the lung is adherent to the diaphragmatic pleura, and the abscess is then evacuated by coughing.

The **anterior surface** of the liver is roughly triangular in outline, the apex being directed to the left and the base to the right. The sharp lower margin of the liver, which forms the inferior boundary of this surface, ascends obliquely as it passes from right to left (Pl. II.). In the subcostal angle, the anterior surface of the liver is in direct contact with the deep surface of the anterior abdominal wall, and it can therefore be examined in this situation both by percussion and by palpation.

On the right side, the anterior surface lies under cover of the costal margin. In its upper part it is overlapped by the pleural sac, and it is only in its lower part that it can be approached without meeting with the pleura. On the left side, the inferior border of the liver forms the right boundary of Traube's space (p. 244).

Surface Marking of the Liver.—When the outline of the liver is determined by percussion on the anterior aspect of the body, it is the anterior surface of the viscus which is mapped out. Under normal conditions, with the patient in the dorsal decubitus, the upper limit of the liver dulness extends upwards into the fourth intercostal space on the right side, but, owing to the thickness of the lung which intervenes between the liver and the chest wall, it is not always easy to determine the upper border with accuracy. Where the upper surface of the liver is in relation to the heart, the limits of the viscus cannot be determined by percussion.

During quiet respiration, the upper border of the anterior surface of the liver corresponds to a line drawn from a point half an inch below and medial to the right nipple to a point 1 inch below and medial to the left nipple. This line passes through the xiphi-sternal junction and shows a slight downward convexity, which corresponds to the lower border of the heart.

The inferior border of the liver can easily be determined by light percussion, which should be begun at some distance below the costal margin. On the right side, the inferior border coincides with the costal margin or projects a little beyond it in the right lateral line, and, as it is traced to the left, it ascends so as to cut the transpyloric plane in the median plane. It then passes upwards more sharply, and crosses the left costal margin opposite the tip of the eighth costal cartilage (Stiles).

In rare cases, a part of the right lobe of the liver, lateral to the gall-bladder (p. 261), projects downwards, sometimes as far as the iliac crest. It is termed **Reidel's lobe.** The condition is congenital and has no pathological bearing. Consequently, care must be taken to avoid mistaking it for an abdominal tumour. A similar downward projection may, very occasionally, be found in connexion with the left lobe of the liver.

In *infants*, the inferior border of the liver usually lies at least half an inch below the costal margin in the right lateral plane. This difference is accounted for partly by the greater

relative size of the viscus (p. 304) and partly by the fact that the ribs are more nearly horizontal.

The **right lateral surface** of the liver lies opposite the seventh, eighth, ninth, tenth and eleventh ribs in the mid-axillary line, and it is separated from them by the lower limit of the pleural sac and the diaphragm. Hepatic dulness can be obtained as high as the sixth intercostal space in the mid-axillary line, but in the sixth and seventh spaces it is masked by the resonant note of the lung, which intervenes between the upper part of this aspect of the liver and the chest wall. In the lower spaces, where the viscus is separated from the parietes only by the diaphragm and pleura, light percussion is sufficient to bring out the dull liver note.

The **posterior surface** of the liver is in contact with the upper part of the posterior abdominal wall, from which it is separated by the œsophagus, on the left side, and the inferior vena cava, on the right side. Little can be learnt from percussion with reference to the extent of this surface, because, to the right side of the median plane, the hepatic dulness merges into the dull note produced by the right kidney (Pl. III.).

The lowest part of the descending thoracic aorta is only separated from the liver by the lower and posterior part of the diaphragm, and its pulsations may be transmitted to the anterior abdominal wall when the left portion of the liver is the site of new growth.

The **inferior surface** of the liver is very oblique and looks downwards, backwards and to the left. On this surface the **obliterated umbilical vein** (**ligamentum teres**) lies in a cleft which serves to separate the liver into right and left lobes (Pl. I.). This subdivision, however, is purely superficial, and the two lobes are directly continuous with one another.

The inferior surface of the *left lobe* is related to the anterior surface of the stomach, which it overlaps in the neighbourhood of the lesser curvature when the body is in the supine position. The inferior surface of the *right lobe* is related, in its

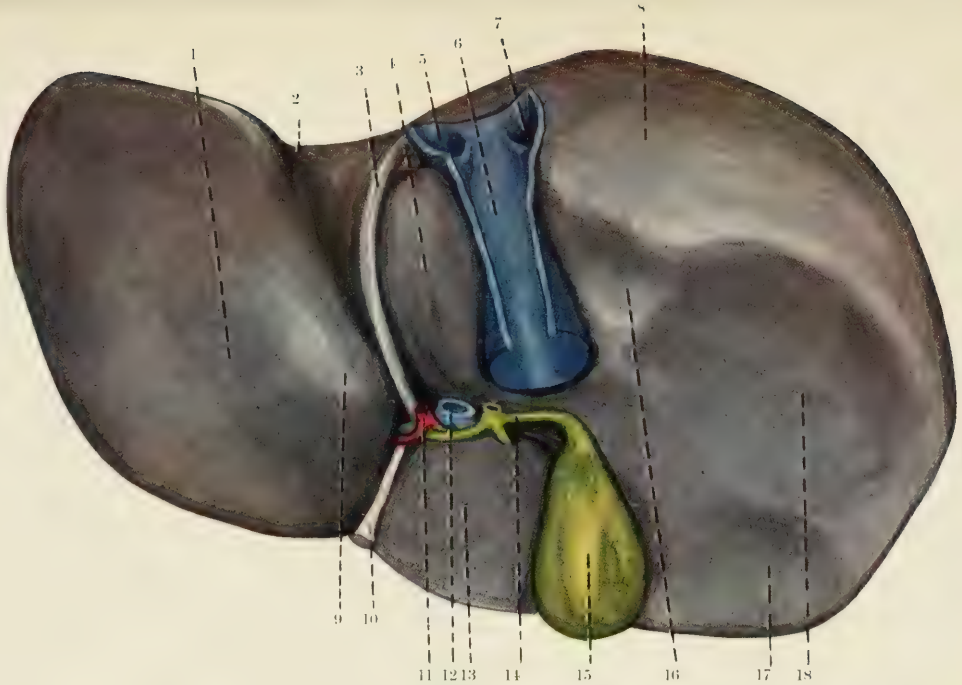


PLATE I. THE POSTERO-INFERIOR ASPECT OF THE LIVER

1. Gastric impression.
2. Oesophageal notch
3. Ligamentum venosum
4. Caudate lobe
5. Orifice of left hepatic veins.
6. Vena cava inferior
7. Orifice of right hepatic veins
8. Bare area.
9. Omental tuber
10. Ligamentum teres.
11. Hepatic artery.
12. Portal vein
13. Quadrate lobe
14. Cystic duct.
15. Gall-bladder.
16. Suprarenal impression
17. Colic impression
18. Renal impression

posterior part, to the right kidney, and, in its anterior part, to the right (hepatic) flexure of the colon. Cases have been recorded in which a tropical abscess has ruptured into the right colic flexure and has been discharged *per anum*.

The **porta hepatis** (**transverse fissure of the liver**) is placed on the inferior surface, and through it the *hepatic artery* and *portal vein* enter and the *hepatic ducts* leave the liver (Pl. I.).

The *hepatic veins*, which join the inferior vena cava just before it pierces the diaphragm, return the blood distributed not only by the hepatic artery but also by the portal vein. Sudden dilatation of the right atrium of the heart dams back the blood in the inferior vena cava, and this backward pressure is at once communicated to the hepatic veins, causing *acute venous congestion of the liver*. In this condition, the size of the anterior surface of the liver is much increased, and the skin and muscles of the upper part of the anterior abdominal wall may be acutely sensitive to ordinary tactile stimuli (*vide infra*). The enlarged liver exhibits pulsations which are identical with the pulsations of the internal jugular vein, as they are brought about in precisely the same way (p. 311). When the dilatation of the right atrium of the heart is more gradual in its onset, *chronic venous congestion of the liver* is brought about and may cause the viscus to project for a considerable distance below the costal margin.

The **Lymph Vessels** of the liver are very numerous. Some pass to the cœliac glands directly, or through the subpyloric glands (p. 249). Others pierce the diaphragm and join the lymph glands in the mediastinal space. Secondary growths, therefore, may be found in the mediastinal glands in primary cancer of the liver.

The **Gall-bladder** forms a small reservoir for the bile secreted by the liver. It occupies a fossa on the inferior surface of the right lobe of the liver, to which it is connected by its peritoneal covering. Its blind extremity or *fundus* projects from under cover of the inferior border of the liver and comes into contact with the anterior abdominal wall, just

medial to the tip of the ninth costal cartilage of the right side. The fundus can be mapped out on the surface in the angle between the right costal margin and the linea semilunaris, which corresponds to the lateral border of the rectus abdominis muscle.

Inferiorly, the gall-bladder is in contact with the duodenum and the commencement of the transverse colon, and it may become adherent to the latter after attacks of cholecystitis. Under these circumstances, gall-stones may rupture into the colon and be discharged by the bowel (Pl. II.).

The *neck* of the gall-bladder narrows to form the **cystic duct**, which enters the porta hepatis and unites with the hepatic duct to form the bile duct. The mucous membrane which lines the cystic duct is redundant and projects into the lumen in the form of oblique folds. These folds may help to prevent the passage of gall-stones from the gall-bladder into the bile duct.

The **Bile Duct** is formed by the union of the cystic with the common hepatic duct at the porta hepatis. It descends from the liver in the right free margin of the lesser omentum, where it lies in front of the portal vein (Fig. 90). It then passes behind the first part of the duodenum and, at the upper border of the head of the pancreas, it diverges from the portal vein, running downwards and laterally behind the head of the pancreas to terminate in the second part of the duodenum (Fig. 97).

In the first, or supra-duodenal, part of its course the bile duct may be compressed by tumours of the liver or by enlarged lymph glands in the porta hepatis. As the duct is closely related to the portal vein in this situation, pressure which affects the duct is almost certain to affect the vein as well.

In the retro-duodenal part of its course, the duct may be obstructed by tumours of the pylorus, which also affect the portal vein. In the terminal part of its course, the duct is not so closely related to the vein, and tumours of the head of the pancreas or chronic pancreatitis are less likely to exert pressure on the vein. They commonly compress the duct

(p. 264) and they may also tend to obstruct the inferior vena cava, which lies behind it.

At its lower end the bile duct pierces the muscular wall of the duodenum very obliquely and opens into a small space, termed the **ampulla of Vater** (Fig. 98), which lies in the submucous tissue. The main duct of the pancreas (p. 269)

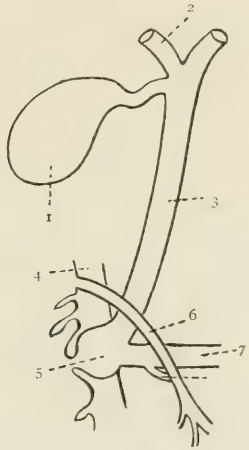


FIG. 98.—Diagram of the Bile Duct and the Pancreatic Ducts, showing how they open into the Duodenum.

1. Gall bladder.
2. Right hepatic duct.
3. Bile duct.
4. Wall of duodenum.
5. Ampulla of Vater.
6. Accessory pancreatic duct.
7. Pancreatic duct.
8. Communication between 6 and 7.

also opens into the ampulla, which possesses a single small opening into the interior of the duodenum. Owing to the obliquity with which the duct pierces the duodenal wall, gall-stones may become impacted before they reach the ampulla of Vater. In this case they are not so likely to obstruct the pancreatic duct, but they may do so if they succeed in entering the ampulla and are unable to pass through the small orifice into the duodenum.

Obstruction of the bile duct is followed by the absorption of bile pigments into the blood, and they are deposited in many of the tissues of the body and under the skin and mucous membranes. When jaundice results from impaction of a gall-stone in the bile duct or from inflammation of the mucous membrane which lines the duct, its onset is sudden, and it is not, as a rule, accompanied by any signs of obstruction to the portal vein or the inferior vena cava. On the other hand, when jaundice results from pressure due to extrinsic causes, the condition is slow in its onset, increases steadily in degree and is frequently associated with signs of venous obstruction.

Development of the Liver and Biliary Passages.—At a time when the stomach is scarcely discernible as a dilatation on the primitive fore-gut (p. 249), the liver arises as a hollow diverticulum from the ventral aspect of the gut immediately caudal to the pylorus. This bud soon bifurcates into two parts, one of which persists as a blind hollow sac and forms the gall-bladder. The cells which line the other proliferate so quickly that its lumen becomes obliterated and the solid mass of cells invades the surrounding mesoderm, which forms the fibrous framework of the liver.

The Nerves of the Liver and Bile Passages.—Owing to the proximity of the point of origin of the liver to the stomach, it is not surprising to find that the sympathetic nerves which supply the liver and bile passages arise from segments of the spinal medulla (T. 7–9) in close relation to the segments which supply the stomach (T. 5–8). In addition, the liver receives branches from both vagi and a few twigs from the right phrenic nerve which descend along the inferior vena cava.

It is well recognised that advanced pathological processes may occur in the liver and yet give rise to no painful symptoms. In this way, the liver closely resembles the lungs, kidneys and pancreas, and it has already been pointed out that these viscera contain very few unstriped muscle fibres In solitary tropical abscess of the liver, the patient often

complains of pain over the right shoulder. In this case, the abnormal afferent stimuli reach the fourth cervical segment of the spinal medulla by the phrenic nerve (p. 128), and "overflow" to the cells which are accustomed to receive stimuli from the posterior supra-clavicular (supra-acromial) nerves. As a result of this overflow stimulus, the patient experiences pain in the skin of the shoulder. It seems doubtful whether the phrenic nerve is affected in the liver itself, and it is more probable that it is involved by inflammatory thickening of the diaphragmatic pleura of the right side.

The gall-bladder and the biliary passages, however, are provided with muscular walls, composed of unstriped muscle fibres, and they can give rise to severe pain which is best exemplified during an attack of **biliary colic**. The passage or the attempted passage of a gall-stone along the bile duct is accompanied by excessive peristalsis of the muscular wall of the duct. As in the case of the alimentary canal, this peristalsis results in the production of acute pain.

Referred pain in connexion with the gall-bladder or bile duct is experienced over the distribution of the peripheral branches of the seventh, eighth and ninth intercostal nerves, usually of the right side only (Fig. 96). In most cases it is restricted to the anterior terminal branches, but it may spread to involve the lateral branches or even the posterior rami (primary divisions). The pain, therefore, is felt over an area which is very similar to that affected in gastric disturbances, but, in the case of the biliary passages, it tends to radiate to the right side of the median plane.

Pathological conditions of the gall-bladder or bile duct may also excite a viscero-motor reflex (p. 197), which shows itself as a localised contraction of the right rectus abdominis in its upper part, *i.e.* that part of the muscle which is innervated by the seventh, eighth and ninth intercostal nerves.

The constant "overflow" of the abnormal afferent impulses from the biliary passages during an attack of biliary colic may establish a "focus of irritation" (p. 195) in the spinal medulla

at the level of the seventh, eighth and ninth thoracic segments. The excitability of the cells in these segments is temporarily increased, and this condition may manifest itself by the presence of areas of cutaneous hyperalgesia (p. 195) in the lower part of the right half of the epigastric region. Some of the nerve-cells connected with the stomach (p. 249) are situated in these segments and consequently, although the gastric mucous membrane may be perfectly healthy, the ingestion of food may give rise to referred pain, since the afferent impulses become exaggerated as they pass through the "focus of irritation."

The bile duct also receives some of the terminal branches of the vagus, and, on this account, a "focus of irritation" may be established in the medulla oblongata following an attack of biliary colic. It seems probable that some such condition is responsible for the occurrence of vomiting at the end of an attack of biliary colic or following the ingestion of food after the cessation of the pain.

It should be remembered that similar reflexes, though of a less pronounced type, may accompany inflammation or other pathological conditions of the gall-bladder or bile duct. Owing to the propinquity of the gastric and the hepatic centres in the spinal medulla, the symptoms produced by cholecystitis may be misinterpreted and they may be erroneously ascribed to some non-existent gastric disorder. For the same reason, the symptoms produced by gastric disturbances may be erroneously ascribed to the gall-bladder, and the diagnosis may only be corrected at a subsequent operation.

The Pancreas

The **Pancreas** is an elongated gland which lies obliquely across the upper part of the posterior abdominal wall. With the exception of its tail, which is situated between the two layers of the lieno-renal ligament (p. 239), the pancreas is entirely retroperitoneal, and it is therefore practically fixed in position.

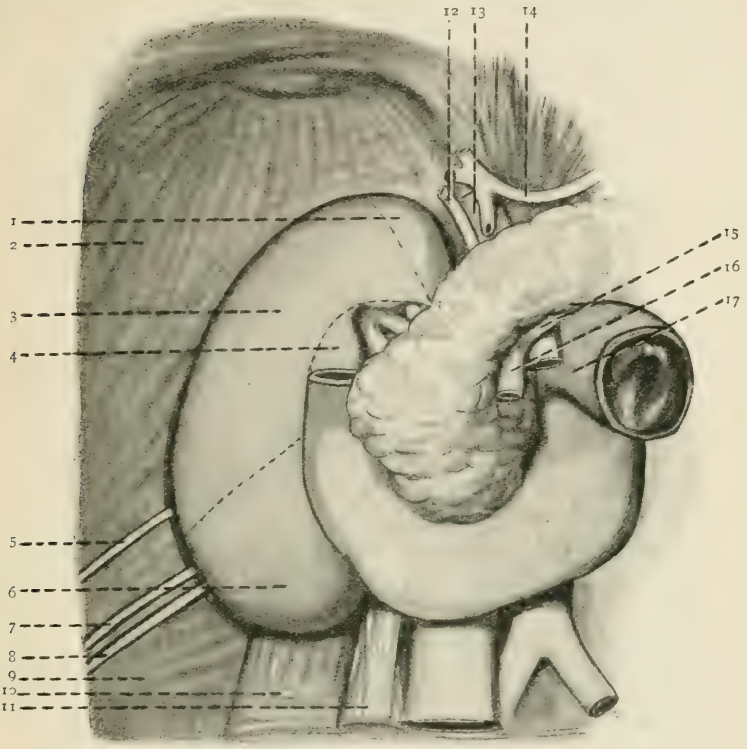


FIG. 99.—The relations of the Right Kidney, the Duodenum and the Head of the Pancreas.

The stomach, the first part of the duodenum, the lesser and greater omenta, the liver and the large intestine have all been removed.

1. Supra-renal area.
2. Diaphragm.
3. Hepatic area.
4. Duodenal area.
5. T. 12 (subcostal nerve).
6. Colic area.
7. Ilio-hypogastric nerve
8. Ilio-inguinal nerve.
9. Transversus muscle.
10. Quadratus lumborum muscle.
11. Psoas major muscle.
12. Bile duct.
13. Portal vein.
14. Hepatic artery.
15. Splenic vein.
16. Superior mesenteric vein.
17. Duodeno-jejunal flexure.

The **head of the pancreas** lies in the C-shaped bend of the duodenum and consequently extends to the right of the median plane. Its anterior surface is related to the transverse colon (p. 280) and to the origin and first part of the portal vein. Posteriorly, the head of the pancreas is in relation to the inferior vena cava and to the bile duct, which descends obliquely behind its upper part (Fig. 99).

This portion of the gland may be the seat of malignant disease and the symptoms produced are, for the most part, referable to the relations which have been enumerated. The bile duct lies in a deep groove in the head of the pancreas and it is very liable to be compressed, giving rise to jaundice which is gradual in its onset but which steadily increases in intensity. The inferior vena cava may be compressed, leading to œdema of the lower limbs, ascites, etc., and the circulation through the portal vein may be interfered with (p. 274).

The **neck and body of the pancreas** extend to the left in front of the abdominal aorta. The body is somewhat triangular on section, possessing anterior, posterior and inferior surfaces, separated from one another by corresponding borders. The anterior border gives attachment to the transverse mesocolon, so that the anterior surface lies in the posterior wall of the omental bursa, where it takes part in the formation of the stomach-bed (p. 245), while the inferior surface looks downwards into the infra-colic compartments.

Tumours in connexion with the body of the pancreas may, when they are of large size, be palpated through the anterior abdominal wall, and they not uncommonly transmit the pulsations of the abdominal aorta. *Pancreatic cysts* usually enlarge on the anterior surface of the gland, so that they project into the omental bursa. If they grow in an upward direction, they may thrust the lesser omentum before them and reach the anterior abdominal wall above the lesser curvature of the stomach, which is displaced downwards and to the left. In this case, percussion indicates an increase in the liver dulness,

but, as the cyst is only covered by the muscular abdominal wall, careful palpation may determine that it is separate from the liver. In most cases, the cyst reaches the anterior abdominal wall below the greater curvature of the stomach, pushing the gastro-colic ligament in front of it. Percussion reveals the presence of a dull area which intervenes between the tympanitic stomach note above and the tympanitic note of the transverse colon below.

The main **duct of the pancreas** begins in the tail of the gland and passes to the right; after traversing the body and head of the pancreas the duct pierces the duodenal wall and opens into the ampulla of Vater (p. 263). Near its termination it may be obstructed by tumours of the head of the gland or by a calculus impacted in the ampulla of Vater. The latter condition is of two-fold interest. In the first place, it may be the forerunner or exciting cause of pancreatitis, as the bile may flow backwards along the pancreatic duct and damage the gland tissue. In the second place, obstruction to the outflow from the main pancreatic duct may be compensated for by the dilatation of a connexion which sometimes exists between the main duct of the pancreas and an *accessory duct.* The latter is confined to the head of the gland and it opens into the duodenum by a separate orifice, placed a short distance above the ampulla of Vater (Fig. 98).

The **Lymph Vessels** of the pancreas terminate in the cœliac glands (p. 249), after passing through the subpyloric, pancreatic and other subsidiary groups. The occurrence of secondary deposits in the pancreas following primary cancer of the stomach has already been mentioned.

Development of the Pancreas.—The presence of two pancreatic ducts, both opening into the duodenum, is explained on reference to the developmental history of the gland. Shortly after the appearance of the diverticulum which forms the liver (p. 264), two similar diverticula grow out from the *ventral* surface of the duodenum, and one of these normally disappears. The other, which is situated at the point where the liver

diverticulum is connected to the duodenum, rapidly proliferates and forms the head of the gland and the terminal part of the main duct.

About the same time, a similar diverticulum grows out from the *dorsal* surface of the duodenum to form the body and tail of the gland. The ventral and dorsal diverticula approach one another and become fused. Their ducts become connected in such a way that the main pancreatic duct is formed by the distal portion of the dorsal duct and the whole of the ventral duct, and it therefore opens into the duodenum in common with the bile duct. The proximal part of the dorsal duct retains its own connexion with the duodenum and persists as the accessory duct of the pancreas. A trace of this developmental change may or may not persist in the presence of a connexion between the accessory and the main pancreatic ducts.

Annular pancreas is a rare congenital anomaly. Normally, the margins of the head of the pancreas overlap the medial border of the second part of the duodenum both anteriorly and posteriorly. These overlapping edges may become so increased in extent that they meet one another at the lateral border of the duodenum, and thus form a complete circle round the gut. The condition may give rise to no symptoms whatever, but, if the gland becomes the site of inflammatory changes, serious obstruction of the duodenum will result.

The **Pancreatic Secretion** contains three important enzymes, which act on the proteid, the fatty and the carbohydrate elements of the food. The flow of pancreatic juice commences when the acid contents of the stomach are expelled into the duodenum. In the presence of an acid medium, the duodenal mucous membrane secretes a substance, termed secretin, which becomes absorbed into the blood-stream and eventually reaches the pancreas, where it causes a rapid flow of the pancreatic secretion. It follows, therefore, that a diminution in the acidity of the stomach contents is accompanied by a diminution in the pancreatic secretion. Under these circum-

stances, digestion is interfered with both in the stomach and in the duodenum.

In the absence of the pancreatic secretion, e.g., *pancreatic infantilism*, and in obstruction to the outflow of the secretion into the duodenum, the most striking feature is due to the absence of the lipolytic enzyme. The digestion of fatty substances is impossible and these constituents of the food are passed unchanged in the fæces. The digestion of proteins and carbohydrates is not so seriously disturbed, as they are acted on by the saliva, the gastric juice and the succus entericus.

At birth, the amylolytic action of the pancreatic secretion is not well developed, although its proteolytic and lipolytic actions are quite normal. When it is remembered that the saliva has little action on carbohydrates during the first year, it becomes quite evident that starchy foods should not form a part of the diet of the infant.

In addition to the secretion which it pours into the intestine, the pancreas possesses an internal secretion. This secretion is formed by groups of polygonal cells, termed the "islands of Langerhans," which have no connexion with the ducts of the gland. It has been suggested that diabetes mellitus is due to insufficiency of the pancreatic internal secretion and the "islands" are found to be degenerated in a certain percentage of cases.

The Portal Circulation

A special description of the portal vein and its tributaries is rendered necessary owing to the frequency with which portal obstruction occurs and owing to the important changes which result from such obstruction.

The **Portal Vein** is formed by the union of the **superior mesenteric** and the **splenic vein** behind the neck of the pancreas. From its origin it passes upwards, lying at first in front of the head of the pancreas and later behind the first part of the duodenum, where it comes into relationship with the bile

duct (p. 262). At the upper border of the duodenum, the vein enters the lesser omentum, in which it ascends to the porta hepatis (transverse fissure of the liver) in company with the bile duct and the hepatic artery (Pl. I.).

At the porta hepatis, the portal vein divides into right and left branches, which enter the right and left lobes of the liver, respectively. These branches eventually break up into capillaries, and thus the blood of the portal circulation passes through two sets of capillaries before it finally returns to the heart.

The effects of portal obstruction can be fully appreciated only after a study of the organs which drain their blood into the portal circulation.

The **Superior Mesenteric Vein** receives tributaries from the following sources:—(1) The terminal part of the duodenum and the whole length of the jejunum and ileum; (2) the cæcum and the vermiform process (appendix); (3) the ascending colon and rather more than the right half of the transverse colon; and (4) the greater curvature of the stomach, through the right gastro-epiploic vein.

The **Splenic Vein** commences at the hilum of the spleen, where the veins which issue from that viscus are joined by the left gastro-epiploic vein, from the greater curvature, and some small veins from the fundus of the stomach. It passes to the right behind the pancreas and receives numerous pancreatic veins. In addition, the splenic vein is joined by the *inferior mesenteric vein*, which receives tributaries from—(1) the left half of the transverse colon; (2) the descending colon; (3) the iliac colon; (4) the pelvic colon; and (5) the rectum.

The portal vein itself receives tributaries from—(1) the lesser curvature of the stomach; (2) the head of the pancreas and the duodenum; and (3) the gall-bladder.

When these various tributaries are summarised, it is found that the portal system drains the spleen, the pancreas, the gall-bladder and the whole of the abdominal part of the alimentary canal with the exception of the anal canal.

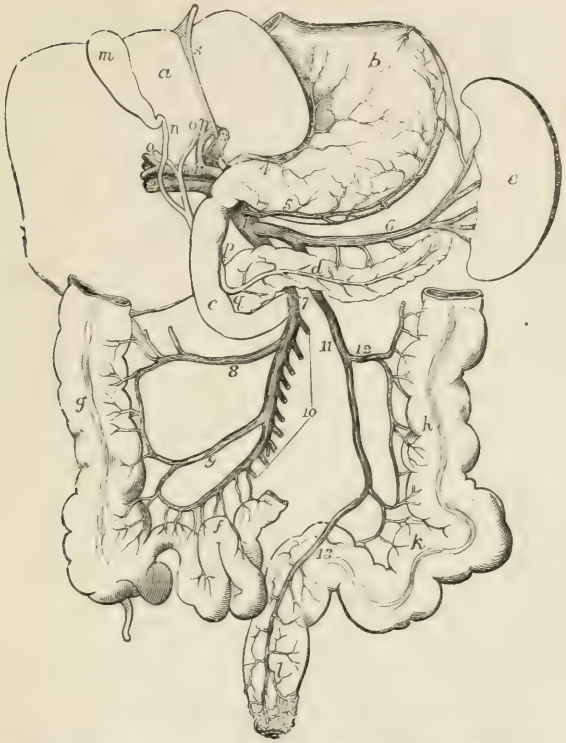


FIG. 100.—The Portal Vein and its Tributaries. (TURNER'S *Anatomy*.)

1. Portal vein.
2. Right branch of portal vein.
3. Left branch of portal vein.
4. Left gastric (coronary) vein.
5. Right gastro-epiploic vein.
6. Splenic vein.
7. Superior mesenteric vein.
8. Right colic vein.
9. Ileo-colic vein.
10. Intestinal veins.
11. Inferior mesenteric vein.
12. Left colic vein.
13. Superior hæmorrhoidal vein.

a. Liver.
b. Stomach.
c. Duodenum.
d. Pancreas.
e. Spleen.
f. Ileum.
g. Ascending colon.
h. Descending colon.
k. Pelvic colon.
l. Rectum.
m. Gall-bladder.
n. Cystic duct.
o. Hepatic ducts.
p. Bile duct, termination of.
q. Pancreatic duct.
r. Hepatic artery.
s. Ligamentum teres.

These, then, are the viscera which will be affected primarily in portal obstruction.

Portal Obstruction. — The portal circulation may be obstructed in the liver itself by hepatic cirrhosis — the commonest cause—or by tumours, either of liver or stomach, in the neighbourhood of the porta hepatis. More rarely, the portal vein may be obstructed by malignant disease of the head of the pancreas. Whatever the cause, the symptoms referable to obstruction of the portal circulation are always the same. The walls of the stomach become the site of venous congestion, the veins become dilated and some may rupture, causing hæmatemesis. A similar condition affects the walls of the alimentary canal, for the larger veins of the portal system do not possess any valves. On this account intestinal derangement, which is usually characterised by alternate periods of diarrhœa and constipation, is brought about and internal hæmorrhoids are found in the lower part of the rectum.

Backward pressure along the splenic vein causes venous congestion of the spleen, which usually becomes enlarged and may project from under the left costal margin. The increase in size of the spleen is one of the most constant concomitants of portal cirrhosis.

Stasis of the mesenteric veins not only affects the intestinal canal, but it also causes an increased transudation of serum into the peritoneal cavity, and, as the peritoneal stomata (p. 240) are not able to remove it with sufficient rapidity, the condition of ascites is brought about. The subsequent action of the stomata is further hampered by a chronic thickening of the peritoneum, which usually accompanies the condition.

Communications between the Portal and the Systemic Veins.—Although obstruction to the portal circulation is only completely compensated in exceptional cases, the condition is always accompanied by a dilatation of the normal channels of communication which connect the systemic to the portal system of veins.

At the upper end of the abdominal alimentary canal, the left gastric (coronary) vein on the lesser curvature communicates with the œsophageal veins, which open indirectly into the superior vena cava. In portal obstruction this anastomosis becomes greatly dilated and may form varices in the lax submucous tissue of the lower part of the œsophagus. Rupture of these veins causes *hæmatemesis* which may be the first sign of portal cirrhosis.

At the lower end of the abdominal alimentary canal, the superior hæmorrhoidal veins, which return their blood *via* the inferior mesenteric and splenic veins to the portal system, communicate freely with the middle and inferior hæmorrhoidal veins, which open indirectly into the inferior vena cava. Dilatation of this anastomosis and the production of *internal hæmorrhoids* is favoured by—(1) the action of gravity, (2) the absence of valves, and (3) the fact that the radicles of the superior hæmorrhoidal veins ascend in the submucous tissue of the rectum for some distance before piercing the muscular wall (p. 284).

The mesenteric and splenic veins communicate with the veins of the posterior abdominal wall, which ultimately open into the inferior vena cava. It is said by some authorities that, in the rare event of complete compensation, it is this anastomosis which carries off by far the greatest part of the obstructed blood.

An extremely interesting communication is established through the medium of the *para-umbilical veins*. These small vessels, which unfortunately are not always present, are connected above to the left branch of the portal vein and they descend on the obliterated umbilical vein (ligamentum teres, p. 260) to the umbilicus, where they establish communications with the superficial veins of the anterior abdominal wall (p. 316). When this anastomosis becomes dilated the superficial abdominal veins are rendered visible through the skin. They are large and tortuous, and they radiate from the umbilicus, so that the general appearance has been termed

the **caput Medusæ.** This condition must be compared with and distinguished from the somewhat similar condition induced by obstruction of the inferior vena cava (p. 316). *In portal obstruction, the blood-stream flows away from the umbilicus.* Some of the veins run upwards and laterally to end ultimately in the superior vena cava, while others pass downwards and laterally to join the femoral vein and so end in the inferior vena cava. The presence of the *caput Medusæ* not only is diagnostic of portal obstruction but it is diagnostic of portal obstruction within the liver itself, for the upper end of the para-umbilical vein is connected to the left branch of the portal vein and, therefore, cannot be involved when the obstruction occurs below the porta hepatis (transverse fissure of the liver).

The Large Intestine

The Cæcum.—The cæcum is that part of the large intestine which lies below the termination of the ileum (Fig. 101). It forms a blind sac, about $2\frac{1}{2}$ inches long and 3 inches wide, which occupies the right iliac fossa, and it can be mapped out on the surface in the area below the inter-tubercular plane and to the lateral side of the right lateral plane (Fig. 101). Under normal conditions, the cæcum is completely invested by peritoneum, and therefore enjoys a certain degree of mobility. The peritoneum on its anterior and lateral aspects is continuous with the corresponding covering of the ascending colon, but the peritoneum on its posterior aspect is reflected backwards from its upper end to the iliac fossa.

So long as its muscular wall is healthy, the cæcum does not extend beyond the right iliac fossa, but when the wall loses its tone, the cæcum tends to sag downwards and medially over the brim of the pelvis. Lane suggests that this latter condition is by no means uncommon and that thickened bands, which pass upwards and laterally and upwards and medially, respectively, from the upper end of the cæcum, are developed in an

endeavour to retain the cæcum in its normal position. These bands may involve the vermiform process or the terminal part of the ileum and cause them to become kinked (p. 256).

The **Vermiform Process** (**Appendix**) springs from the medial border of the cæcum near its lower end. It is completely covered with peritoneum but differs from the cæcum in that it possesses a mesentery, which contains the appendicular artery in its free border. The vermiform process is usually about

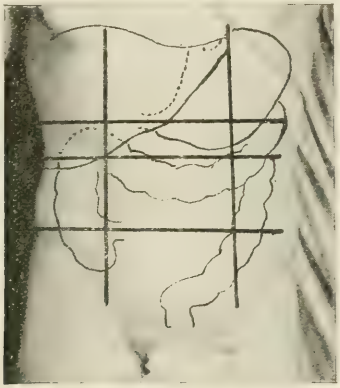


FIG. 101.—Anterior Aspect of the Trunk, showing the surface relations of the liver, the stomach and the large intestine.

NOTE.—The reference lines are the same as those shown in Fig. 87.

3 inches long, but it varies greatly in length and may measure from $1\frac{1}{2}$ to 10 inches. Owing to its peritoneal relations, it possesses a wide range of movement and it is impossible to foretell where it will be found when an operation is performed for its removal. In certain cases of appendicitis, increased frequency of micturition is a prominent symptom, and it is held by some authorities that this condition only occurs when the vermiform process passes downwards into the pelvis and becomes adherent to the bladder. Another explanation, however, is possible, as will be shown later (p. 279).

Development of the Cæcum and Vermiform Process.—During the third week a localised dilatation appears on the anti-mesenteric border of the hind-gut (p. 286). After a time, the calibre of the proximal part of the dilatation increases in the same proportion as the rest of the intestinal tube, but the distal part remains relatively much smaller in diameter, although it continues to increase in length. This is the first sign of the formation of the vermiform process, which at first springs from the apex of the cæcum. After birth, the lateral wall of the cæcum grows much more rapidly than the medial wall, so that the vermiform process in the adult springs from the medial wall of the cæcum and not from its apex.

During the development of the cæcum, the intestinal tube increases in length and forms a U-shaped loop, which is suspended from the posterior abdominal wall by a dorsal mesentery. The cæcum lies on the distal limb of the U. The loop becomes rotated counter-clockwise through 180°, so that the distal limb of the U is carried across the anterior surface of the proximal limb. After this rotation of the gut has taken place, the cæcum lies in contact with the lower surface of the right lobe of the liver. At birth, however, it is found normally in the right iliac fossa, but, not infrequently, the cæcum and vermiform process are found at operations in the infra-hepatic position.

The Nerve-supply of the Cæcum and the Vermiform Process is derived from a number of sympathetic nerves which accompany their arteries of supply. These nerves have their centres in the region of the eleventh thoracic segment of the spinal medulla.

In the early stages of appendicitis the pain is usually experienced in the median plane, at or just below the umbilicus, and it is perfectly clear that we are here dealing with an example of the viscero-sensory reflex (p. 192). The abnormal afferent stimuli may "overflow" from the eleventh segment and affect the adjoining segments. As a result, the pain is not confined to the area supplied by the eleventh intercostal nerve,

but it is also experienced in the areas supplied by the tenth and twelfth thoracic nerves.

At a later stage, the most acute pain is experienced over M'Burney's point, which lies on the right lateral plane 1 inch below the intertubercular plane and corresponds to the point where the vermiform process springs from the cæcum. At this point, too, there is usually tenderness to deep pressure. It is by no means certain whether these pains are actually felt in the viscus or whether they are felt in the abdominal wall. It is said that in cases of appendicitis, in which the vermiform process has been subsequently found in the infra-hepatic position, there is no pain or tenderness over M'Burney's point, but these cases are not of frequent occurrence and they have not yet received sufficient attention.

Cases of appendicitis may give rise to the viscero-motor reflex. This is represented by a localised contraction of the lower parts of the lateral abdominal muscles. It is curious that these areas of muscular contraction usually overlie the affected viscus, for, as already mentioned, the vermiform process develops in the median plane and its position in the right iliac region is assumed some months after it has received its nerve-supply.

In pathological lesions of the cæcum or the vermiform process, slight tonic contraction of the right psoas major may occur, as evidenced by slight flexion of the hip-joint. The muscle lies to the medial side of the cæcum, and it is possible that it is only affected when its sensory nerves are irritated, *e.g.*, by the presence of an abscess. Mackenzie believes that the condition may be accounted for by the presence of a "focus of irritation" in the spinal medulla, and he suggests that the frequency of micturition, associated with some cases of appendicitis, may be explained in the same way.

The *mucous membrane* of the cæcum and the vermiform process is richly provided with lymphoid tissue, and these parts of the intestinal canal may, therefore, be the site of ulceration and, sometimes, perforation in *typhoid fever*.

The **Colic (Ileo-cæcal) Valve** guards the opening of the ileum into the cæcum and prevents the regurgitation of the contents of the cæcum into the ileum. It can be indicated on the surface of the body at the intersection of the intertubercular and the right lateral planes (Fig. 101).

The **Ascending Colon** begins at the upper end of the cæcum and passes upwards on the posterior abdominal wall till it reaches the inferior surface of the right lobe of the liver, where it bends forwards and to the left, forming the *right (hepatic) flexure of the colon.* It is about 6 inches long and it lies behind the peritoneum, save in exceptional cases where it possesses a dorsal mesentery.

This part of the colon can be mapped out on the surface to the lateral side of the right lateral plane, and it extends from the intertubercular plane to the ninth costal cartilage (Fig. 101).

The **Right Colic Flexure** is placed under cover of the right costal margin. Posteriorly it lies on the right kidney, and anteriorly it is related to the liver and the gall-bladder. In this situation the colon and the gall-bladder may become adherent to one another following cholecystitis, and gall-stones may find their way into the gut and be discharged *per anum.*

The **Transverse Colon** is about 20 inches long and it forms a U-shaped loop, which is suspended from the posterior abdominal wall by the transverse mesocolon.

It extends from the right flexure to the **left (splenic) flexure of the colon,** both of which are, within limits, fixed in position. The transverse colon, however, by virtue of its mesentery, may alter its position from time to time and, in radiograms taken in the vertical posture, its lowest point is usually a little above the upper border of the pubic symphysis, but it may descend still farther without justifying a diagnosis of viscero-ptosis.

When the patient is in the dorsal decubitus, the transverse colon may be indicated as a widely open U. The lower border lies at, or a little below, the umbilicus, while the left

extremity passes upwards under cover of the costal margin for an inch or more above the transpyloric plane and immediately lateral to the left lateral line (Pl. II.).

Above, the transverse colon is related to the stomach, and the interposition of a dull area between the two is suggestive of pancreatic cyst or tumour.

The **Descending Colon** is only about 4 inches long and is entirely retro-peritoneal. It extends vertically downwards from the left colic flexure to the iliac crest, and it is placed more deeply in the abdominal cavity than the ascending colon, being separated from the anterior abdominal wall by coils of small intestine.

The **Iliac Colon** runs downwards and medially across the left iliac fossa, from the iliac crest to the brim of the pelvis. In its lower portion it lies parallel to and a little above the lateral half of the inguinal ligament (of Poupart). Normally, coils of small intestine intervene between the iliac colon and the anterior abdominal wall, but tumours of this part of the bowel can be palpated when deep pressure is used, owing to the resistance offered by the ilium.

The **Pelvic Colon** varies considerably in length, but it always possesses a definite mesentery. It may be as short as 6 and as long as 16 inches, and its coils usually lie within the pelvis in relation to the rectum, the bladder and the terminal coils of the ileum.

The **Rectum,** which is about 5 inches long, commences opposite the third sacral vertebra, where it is continuous above with the pelvic colon. In its upper third, it is covered with peritoneum anteriorly and on each side; in its middle third, it is covered only on its anterior aspect. At the junction of the middle and lower thirds of the rectum, the peritoneum passes forwards, forming the floor of the pelvic compartment of the peritoneal cavity, and reaches the bladder, in the male (the upper part of the posterior wall of the vagina in the female, Figs. 127 and 134). The lower third of the rectum is therefore devoid of peritoneal covering.

As it descends through the pelvis, the rectum follows the curve of the sacrum and coccyx, and 1 inch in front of the tip of the coccyx it bends sharply backwards and downwards to join the anal canal. When it is examined *in situ* from in front it is found that the rectum bulges to the left side of the median plane. It possesses three lateral flexures. At first it bends to the left and then to the right, so as to regain the

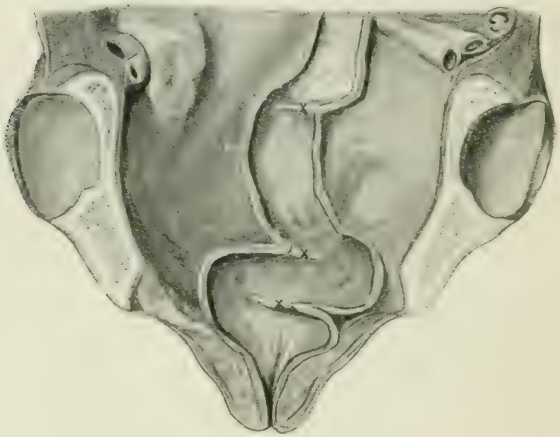


FIG. 102.—The Rectal Valves.

An oblique frontal (coronal) section has been made through the pelvis so as to pass through the anal canal. In addition, the anterior wall of the rectum has been removed and the rectal valves (×) are exposed. The lateral flexures of the rectum are well shown.

median plane, but it does not pass over to the right side. Instead, it bends for a third time, so that its lower part lies in the middle line. On the concave side of the lateral flexures, the mucous membrane projects into the lumen of the gut forming horizontal folds, termed the *rectal valves.* The highest and the lowest of the three lie on the left wall of the gut, while the middle valve lies on the right wall. The lowest valve can be reached with the tip of the finger on rectal

examination. When the rectum becomes distended, the valves form shelf-like ledges, which help to support the contents.

Posteriorly, the rectum lies in contact with the sacrum and coccyx, against which scybalous masses may be compressed and broken down. The large nerve trunks which form the left sacral plexus lie behind the rectum, before they leave the pelvis to enter the gluteal region. When the rectum is greatly distended, it may overlap and compress both sacral plexuses. As a result of this pressure, painful symptoms are experienced in the back of the thigh and the condition may be mistaken for true sciatica (p. 182). Complete evacuation of the bowel, however, effects a speedy cure in these cases.

Anteriorly, the rectum is related to the posterior surface of the bladder, the terminal parts of the ductus deferentes (vasa deferentia), the seminal vesicles and the prostate. All of these structures can be palpated on digital examination of the anterior wall of the rectum. (The examination of the rectum in the female is referred to on page 388.)

The terminal part of the rectum is supported by the levatores ani muscles (p. 184), which separate it, on each side, from the ischio-rectal fossa.

In rapid wasting conditions in childhood, the amount of fat in the ischio-rectal fossæ is much diminished, and the rectum thus loses a certain amount of support. As the curvature of the sacrum is less pronounced in the child than in the adult, *prolapse of the rectum* may occur in these cases during violent straining efforts to empty the bowel.

The **Anal Canal** passes downwards and backwards through the floor of the pelvis to open on the surface of the perineum. The mucous membrane lining the upper part of the anal canal is continuous with the mucous lining of the rectum and is characterised by numerous longitudinal ridges, which are united at their lower ends by transverse folds termed the *anal valves*. During the passage of a scybalous mass one of the little pockets formed by the valves may be torn, and this laceration constitutes the condition which is termed *anal fissure*.

The lower part of the anal canal is lined by modified skin. This difference in structure indicates a difference in developmental origin (p. 287), and is characterised by a difference in nerve-supply. Thus, the upper part of the anal canal is supplied through the sympathetic system, while the lower part is supplied by the pudendal (internal pudic) nerve (p. 183).

The **Hæmorrhoidal Venous Plexus** is situated in the submucous tissue of the anal canal. The importance of this plexus depends on the fact that it constitutes a free communication between the superior hæmorrhoidal vein, which passes, *via* the inferior mesenteric and the splenic, to the portal vein, and the middle and inferior hæmorrhoidal veins, which pass *via* the hypogastric (internal iliac) and common iliac veins to the inferior vena cava.

The *superior hæmorrhoidal vein* ascends for some distance in the submucous tissue of the rectum before it pierces the muscular wall of the gut, and it is, therefore, subjected to compression during defæcation. In portal obstruction (p. 274) or in chronic constipation, the blood is dammed back in the superior hæmorrhoidal vein and the pressure in the hæmorrhoidal plexus is greatly increased. As the submucous tissue in which they lie is very distensible, the veins of the plexus become varicose and constitute the condition known as internal hæmorrhoids.

Irrigation of the Large Intestine is frequently necessary in children suffering from epidemic enteritis, and it is important that the gut should not be overdistended by the introduction of more fluid than it can contain without dilating. Holt estimates that at six months the colon will hold not more than 1 pint, while at two years $2\frac{1}{2}$ to 3 pints can be introduced without distending the gut.

The Nerve-supply of the Large Intestine.—The large intestine, from the cæcum to the pelvic colon, inclusive, is supplied by sympathetic nerves which have their centres situated in the lower thoracic and upper lumbar segments of the spinal medulla. The rectum receives some fibres from the

same source, but, like the urinary bladder (p. 371), it is also supplied by sympathetic fibres which have their centres situated in the mid-sacral segments. The latter fibres constitute the *pelvic splanchnics of Gaskell* and they also supply the upper part of the anal canal. On the other hand, the lower part of the anal canal is supplied through the cerebro-spinal system by the pudendal nerve (S. 2, 3 and 4).

Violent peristalsis of the large intestine, such as occurs in griping, gives rise to pain, which is often referred to the peripheral distribution of the anterior rami (primary divisions) of the eleventh and twelfth thoracic and the first lumbar nerves, and especially to their anterior cutaneous branches (Fig. 69). It is consequently experienced most acutely in the hypogastric region, though it may also be referred to the iliac regions and the lateral part of the buttock.

In new growths or ulceration of the rectum, pain is frequently referred to the perineum or to the back of the sacrum, and, in rare cases, it is experienced in the back of the thigh. Reference to Figs. 69 and 74 will show that these cutaneous areas are supplied by spinal nerves which all arise from the same segments of the spinal medulla. Further, these segments also give rise to the pelvic splanchnics, which supply the rectum.

The extreme tenderness of the anal canal in the presence of a fissure is purely local, for, since it is the lower part of the canal which is abraded in this condition (p. 283), the sensory branches of the pudendal nerve are directly stimulated. The accompanying contraction of the sphincter ani externus, which is also supplied by the pudendal nerve, is a good example of the viscero-motor reflex.

Developmental Anomalies of the Intestinal Canal. —**Atresia ani** and the presence of some form of **Meckel's diverticulum** are the two commonest congenital abnormalities met with in the alimentary canal.

At an early stage the primitive alimentary canal consists of a simple tube, closed at both extremities but open on its ventral aspect, where it communicates with the *yolk-sac*

(Fig. 1). This connexion, which is termed the *vitello-intestinal duct*, becomes relatively smaller, as the gut increases in length, and it normally becomes obliterated entirely. It may, however, persist, and the highest degree of persistence consists in the presence at birth—after the umbilical cord has been divided—of an umbilical fæcal fistula. In the commonest variety, the proximal part of the duct remains as a short blind diverticulum on the anti-mesenteric border of the ileum about 3 feet from its termination. This variety of

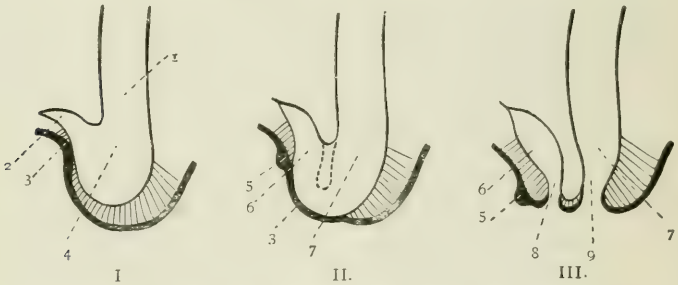


FIG. 103.—The Development of the Bladder and Rectum.

In I., the cloacal membrane is just beginning to form. In II., it is very extensive, and the cloaca is being divided into ventral and dorsal portions. In III., the sub-division of the cloaca is complete and the uro-genital and anal membranes have ruptured.

1. Hind-gut.
2. Allantois.
3. Cloacal membrane.
4. Cloaca.
5. Genital tubercle.
6. Ventral, urinary, part of cloaca.
7. Dorsal, gut, part of cloaca.
8. Perineal orifice of uro-genital sinus.
9. Anal orifice.

persistent vitello-intestinal duct constitutes a **Meckel's diverticulum**, and it is of importance because it may become adherent to the mesentery and give rise to intestinal obstruction.

The blind posterior part of the primitive alimentary canal is known as the *hind-gut*. A small diverticulum, termed the **allantois**, passes from the ventral wall of the hind-gut, near its cephalic extremity, into the body-stalk (Fig. 103). The part of the hind-gut which lies caudal to the allantois is termed the **cloaca**, and it subsequently becomes divided into a ventral or urinary, and a dorsal or intestinal, segment. While this

subdivision is in progress, the mesoderm separating the ventral wall of the cloaca from the ectoderm disappears over an area which is termed the **cloacal membrane**.

When the subdivision of the cloaca is completed, it is found that the cloacal membrane also has been divided into two corresponding parts, which are termed the urogenital and anal membranes, respectively. The anal membrane becomes depressed to form the **proctodæum** and it finally breaks down, so that the anal canal opens on the surface of the body (Fig. 103). During the subdivision of the cloacal membrane, the mesoderm grows into the central area so as to separate the urogenital and anal membranes from one another. If it grows in between the ectodermal and endodermal layers of the anal membrane, the membrane fails to break down and the condition of **atresia ani** results.

It will be seen from Fig. 103, III., that the lining of the upper part of the anal canal is derived from entoderm, while that of the lower part is derived from ectoderm.

IV

THE VASCULAR SYSTEM

The Pericardium.—The Pericardium is a fibro-serous sac which encloses the heart and the roots of the great vessels. It is shaped like a truncated cone, the base being directed downwards and the apex upwards. Inferiorly, the outer **fibrous layer** of the pericardium is blended with the central tendon of the diaphragm, so that the possible amount of lateral displacement of the heart is strictly limited. As the great vessels pierce the pericardium, the fibrous layer is prolonged upon them for varying distances. On the aorta, it becomes blended with the pretracheal layer of the deep cervical fascia, which descends into the thorax on the anterior aspect of the trachea. This connexion may, perhaps, help to produce the clinical phenomenon of "tracheal tugging," which is found in association with aneurisms of the aortic arch (see also p. 321).

The **serous pericardium** consists of a parietal layer which lines the fibrous pericardium, and a visceral layer which is reflected on to the heart and constitutes the *epicardium* (Fig. 104). In this way, the heart is enveloped in a completely closed serous sac, so that its action becomes greatly impeded when the sac is distended by effusions. As the aorta and pulmonary artery leave the heart, they are surrounded by a common tube-like continuation of the epicardium, about 1 inch long, which becomes continuous with the parietal layer of the sac. The superior vena cava does not possess a similar covering, and is only clothed on its anterior and lateral

aspects by the serous pericardium. A small pocket of the pericardial sac, therefore, lies in front of the termination of the superior vena cava (Fig. 105), and, when it is distended with fluid, it may exercise pressure on the vessel, giving rise to venous engorgement on both sides of the head and neck and in both upper limbs.

On each side, the pericardium is related to the medial

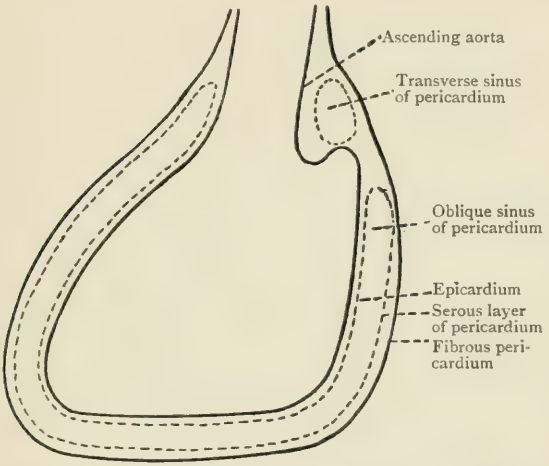


FIG. 104.—Diagram of a Sagittal Section through the Heart and the Pericardium.

surface of the lung from which it is separated by the mediastinal pleura. Pericardial effusions are sometimes so large that they may compress the lungs and so superimpose pulmonary dyspnœa on the existing cardiac dyspnœa.

Posteriorly, the pericardium is related to the descending thoracic aorta and to the œsophagus, which intervene between it and the vertebral column. When food passes down the œsophagus, the tube is bulged forwards and pressed against the posterior aspect of the pericardium. In pericarditis,

swallowing is often a painful process, and the pain is referred to the terminal branches of the upper intercostal nerves. The occurrence of this symptom in cases of acute rheumatic fever may be the first indication of pericardial involvement.

Anteriorly, the pericardium is partly overlapped by the lungs and pleural sacs, but it is in direct contact with the sternum over a small area (Fig. 106). In young children the

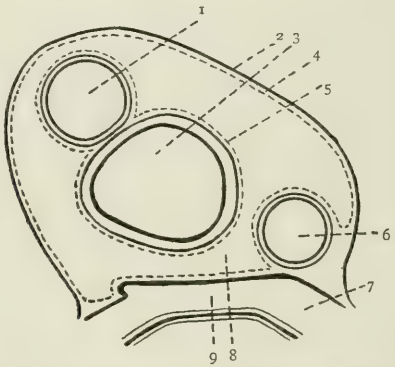


FIG. 105.—Diagram of a Transverse Section through the upper part of the Pericardium.

The serous layer of the pericardium is represented by the dotted line.

1. Pulmonary artery.
2. Fibrous layer of pericardium.
3. Ascending aorta.
4, 5. Serous layer of pericardium.
6. Superior vena cava.
7. Right pulmonary vein.
8. Transverse sinus of pericardium.
9. Upper extremity of left atrium (auricle).

dulness obtained on percussion over this area may be continued upwards to the upper border of the sternum. This phenomenon usually indicates the presence of a large thymus (p. 413). The area of contact with the anterior thoracic wall becomes greatly increased in large effusions, owing to the retraction of the anterior borders of the compressed lungs. In these cases it may be possible to determine by percussion that the dulness extends over an area which corresponds to the conical shape of the pericardial sac.

It should be remembered that large pericardial effusions thrust the heart forwards against the chest wall, so that the introduction of a cannula at the border of the sternum is certain to result in injury to the heart. The fluid collects posteriorly and on each side of the heart, and on this account the operation of *paracentesis pericardii* is best carried out at the left extremity of the dull area and through the fifth intercostal space. As a rule the instrument will pass through the left pleural sac, but this injury is not followed by any bad results. The instrument is thrust backwards and slightly medially, and its entry into the pericardial sac is indicated by the cessation of resistance to its passage.

Inferiorly, the pericardium is supported by the diaphragm, which separates it from the upper surface of the liver. Pericardial effusions may displace the liver in a downward direction, so that its lower border may be palpated below the costal margin.

Superiorly, the upper limit of the pericardial sac surrounds the ascending aorta and the pulmonary artery and comes into relation with the left bronchus. In pericardial effusions, the bronchus may be compressed, thus increasing the respiratory embarrassment, or it may be thrust upwards so as to compress the left recurrent (laryngeal) nerve, as it hooks round the inferior aspect of the arch of the aorta (Purves Stewart).

In adhesive mediastinitis, the fibrous layer of the pericardium becomes firmly anchored to the sternum and costal cartilages in front and to the posterior thoracic wall behind. When the ventricles contract, the left interspaces are drawn inwards on the front of the chest, and a similar indrawing may be observed in the lower left interspaces on the dorsal aspect of the body. In this condition, the heart is called upon to work at an obvious disadvantage, and, in order that it may efficiently perform its functions, it requires to undergo a great amount of hypertrophy, which is usually accompanied by some degree of dilatation.

On the other hand, adhesions arising within the pericardial

sac, as a result of pericarditis, give rise to no characteristic signs beyond dilatation and hypertrophy of the heart.

The Heart

The **Heart** is situated within the pericardium in the middle mediastinum. Its *posterior surface*, which consists of the two **atria** (**auricles**), is placed opposite the fifth, sixth, seventh and eighth thoracic vertebræ and is separated from them by the pericardium, the œsophagus and the descending thoracic aorta. The *antero-superior surface* is in relationship to the lungs and pleural sacs and to the anterior chest wall, and it is the outlines of this surface which are represented when the heart is mapped out on the anterior surface of the body. It comprises—(1) The **right atrium**, which occupies the right portion of the area; (2) the **right ventricle**, which forms the large central area; (3) the **left ventricle**, which is only represented by a narrow strip along the left border; (4) the **left auricle** (**auricular appendix**), which forms the left upper corner of the surface.

The *inferior surface* of the heart rests on the diaphragm, by which it is separated from the superior surface of the liver and the antero-superior surface of the stomach. It consists of a small portion of the right atrium, which is placed to the right and posteriorly, but most of the surface is formed by the ventricles. Hyperdistension of the stomach may influence the heart's action—(1) by mechanical pressure, and (2) reflexly, through the vagus nerves.

The **Right Atrium** (**Auricle**) receives the blood from the great systemic veins and expels it through the right atrio-ventricular orifice into the right ventricle. The opening of the superior vena cava is placed at the right upper extremity of the atrium and is not guarded by a valve. The opening of the coronary sinus, which returns the blood from the heart wall, and the opening of the inferior vena cava are placed at the lower part of the chamber and both are guarded by slender

folds of endocardium, but these primitive valves are never competent to prevent regurgitation.

On the posterior wall of the right atrium, which is formed by the interatrial (interauricular) septum, there is a definite oval depression, termed the *fossa ovalis*. This depression occupies the site of the fœtal *foramen ovale* (p. 303), and a small slit-like opening is often found in its upper part, but usually it is not of sufficient size to have any pathological or clinical significance.

The **right atrio-ventricular orifice**, when normal in size, admits the tips of three fingers. It is guarded by a valve of three cusps, which consist of folds of redundant endocardium. These folds hang down into the interior of the ventricle and give attachment to a number of fine tendons, termed *chordæ tendineæ*, which are attached at their lower extremities to the apices of the *papillary muscles*. A fibrous ring surrounds the orifice and gives attachment to the upper borders of the cusps.

The **Right Ventricle** receives the blood from the right atrium and pumps it along the pulmonary artery into the lungs. Its walls are roughened by numerous muscular bands which are known as the *trabeculæ carneæ*. The most important of these bands are the *papillary muscles*, which are attached to the ventricular walls by their bases and give origin, at their apices, to the *chordæ tendineæ*. It is owing to the action of the papillary muscles that the tricuspid valve is able to prevent the regurgitation of blood from the right ventricle into the right atrium (p. 300).

The **Left Atrium** receives the blood from the pulmonary veins and expels it through the **left atrio-ventricular (mitral) orifice** into the left ventricle. It is deeply placed and is hidden from view anteriorly by the ascending aorta and the pulmonary artery.

The left atrio-ventricular orifice, when normal in size, admits the tips of two fingers. It is guarded by the bicuspid valve, which, save that it possesses only two cusps, corresponds in every way to the tricuspid valve.

The **Left Ventricle** pumps the blood into the ascending aorta, and its walls, which possess trabeculæ carneæ, papillary muscles, etc., are very similar to those of the right ventricle, except that they are nearly three times as thick.

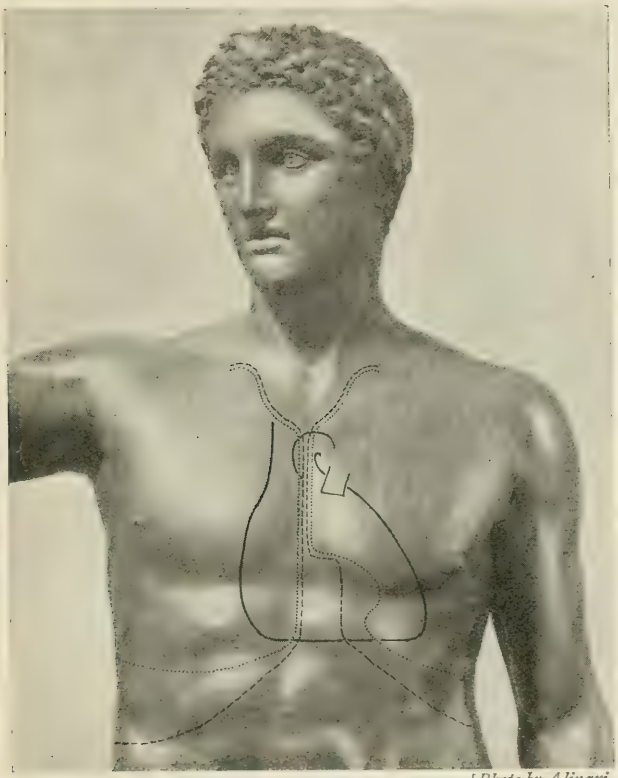
The orifices of the pulmonary artery and the aorta are guarded by endocardial valves, which consist of three *semilunar cusps*. During ventricular systole, the cusps are pressed apart and separated, but during diastole they are thrust together across the orifice and so prevent regurgitation into the ventricles.

Surface Relations of the Heart.—In mapping out the antero-superior surface of the heart, the identification of the individual ribs is essential. The union between the manubrium and the body of the sternum is marked by a transverse ridge, which can readily be felt through the skin. At the extremities of this ridge, which is termed the **sternal angle (of Louis)**, the second costal cartilages articulate with the sternum and they can be identified, therefore, in every case. The third, fourth and fifth costal cartilages can be distinguished without difficulty, but it is not easy to identify the succeeding cartilages, as the spaces between them are much narrower.

The **right border** of the heart can be mapped out by a line which commences above on the right third cartilage, and descends with a slight convexity to the right. Opposite the fourth intercostal space this line reaches its maximum distance —about 1½ inches—from the median plane, and it terminates below on the sixth costal cartilage 1 inch from the median plane. This border is formed by the right atrium (auricle) alone.

The **inferior border** of the heart can be represented by a line which begins at the lower extremity of the right border and passes to the left to reach the position of the apex-beat. Under normal conditions the apex of the heart lies in the fifth left intercostal space at a distance of 3½ inches from the median plane. The lower border of the heart is formed, for

the most part, by the right ventricle, but its left extremity corresponds to a part of the left ventricle.



[*Photo by Alinari.*

FIG. 106.—Anterior Aspect of the Chest, showing the surface relations of the heart and great vessels, the lungs and the pleural sacs.

..... Border of lung.
– – – – – Lines of pleural reflection.

The **left border** of the heart can be represented by a line which begins at the apex and extends upwards and medially, with a gentle convexity to the left, to reach the lower part of

the second left intercostal space, about half an inch from the left margin of the sternum. This line corresponds to the margin of the left ventricle, but at its upper end it outlines the left auricle (auricular appendix).

The area which is mapped out by these borders corresponds to the antero-superior surface of the heart. The greater part of this surface is covered by the anterior margins of the lungs, but, owing to the presence of the incisura cardiaca (p. 349) on the left side, a small part is not covered by the left lung. This small area consequently yields a dull note on light percussion, and is termed the area of **superficial cardiac dulness**. It is roughly triangular in shape. Its right border is situated in the median plane and extends from the level of the fourth to the level of the sixth costal cartilage, a distance of about $1\frac{1}{4}$ inches. From this line the area of superficial dulness can be traced to the left, but it rapidly diminishes in vertical extent. The lower border of the area coincides with the intermediate portion of the lower border of the heart, and the upper border descends to meet it at a point about 1 inch medial to the apex-beat (Fig. 106). In mapping out the area of superficial cardiac dulness very light percussion is employed, because of the thinness of the adjoining lung margins.

Although no part of the area of superficial cardiac dulness is covered by lung, that part of it which lies beyond the left side of the sternum is covered by the left pleural sac.

Increase in the size of the area of superficial cardiac dulness may be due to one of several causes. Factors which tend to cause the lungs to retract or collapse, *e.g.* pulmonary tuberculosis, pneumothorax, pericardial effusions, cardiac hypertrophy, etc., produce a real increase in extent. Left- or right-sided pleural effusions, when they rise as high as the sternal extremity of the fifth costal cartilage, increase the lateral extent of the area, but the increase is not a true increase inasmuch as it is not formed by the heart. In young children, an

apparent increase in the vertical extent may be due to the persistence of a large thymus.

Decrease in the size of the area of superficial cardiac dulness can only be due to one cause, namely, emphysema. This condition affects the least supported parts of the lungs, and, therefore, the thin anterior borders are always involved at an early stage. The margins of the incisura cardiaca are especially liable to be involved, as they can be greatly distended without necessitating stretching of the parietal pleura (Fig. 106).

With the exception of the area of superficial cardiac dulness, the whole of the antero-superior surface of the heart is covered by the margins of the lungs, which, in this situation, are not thick enough to obscure the dull cardiac note on firm percussion over the cardiac area. On this account, the position of the right and left borders of the heart can be determined by percussion, but it is practically impossible to determine the position of the lower border by percussion alone, as the dull cardiac note merges into the dull note of the liver.

In **dilatation or hypertrophy of the right ventricle** the lower border of the heart is displaced in a downward direction. Although this alteration may not be easy to detect by means of percussion, inspection alone may be of great value in determining the condition. The downward enlargement produces well-marked pulsation in the epigastrium, and the character of the pulsation is quite different from that due to the abdominal aorta in neurasthenic patients or to aneurism of that vessel. In enlargement of the right ventricle, the collapse or recession of the epigastrium synchronises with ventricular systole, as it is due to the diminution of the chamber in volume during the contraction. On the other hand, in epigastric pulsation due to the abdominal aorta the forward movement of the epigastrium synchronises with ventricular systole.

As the right ventricle enlarges, the left ventricle is displaced in a backward direction and the apex-beat can no longer be

seen. Instead, there is a visible indrawing of the fourth and fifth intercostal spaces on the left side during systole, and this pulsation is similar in character to the pulsation in the epigastrium. This condition must be distinguished from the sucking in of the same interspaces caused by adherent pericardium (p. 291).

Enlargement of the right ventricle is usually accompanied by an increase in size of the right atrium (auricle). Such an increase can be determined by percussion since it results in displacement of the right border to the right side, the left border remaining normal or being displaced to the left.

It must be remembered that the heart may be thrust bodily over to the right by the pressure of a left-sided pleural effusion or pneumo-thorax, but in these cases the apex-beat is not found in its normal position and the left border of the heart is displaced medially.

Enlargement of the left ventricle is indicated by displacement of the apex-beat downwards and to the left, while the distance of the left border of the heart from the sternum is found, on percussion, to be greater than normal. In this case, also, it must be remembered that the heart may be thrust over to the left by a right-sided pleural effusion or pneumothorax, but, under these circumstances, the position of the right border will be similarly altered.

Dilatation of the left atrium (**auricle**) does not enlarge the area of cardiac dulness, unless the left auricle (auricular appendix) is affected, and, in that case, cardiac dulness may be discovered on percussion over the sternal end of the second left intercostal space.

Unless coincident with pulmonary emphysema, the enlargement of any of the chambers of the heart, except the left atrium, results in an increase of the area of superficial cardiac dulness, since the enlarging chamber pushes the lungs aside.

In mapping out the antero-superior surface of the heart *in the child*, the methods indicated above may be followed, due allowance being made for the difference in size. Although,

in the adult, the apex-beat is found in the fifth intercostal space medial to the nipple line, in children under the age of four it is usually situated in the fourth intercostal space and it lies lateral to the nipple line.

Surface Relations of the Valves of the Heart.—The **pulmonary valve** lies behind the upper border of the third costal cartilage of the left side, close to its articulation with the sternum, and the **aortic valve** lies on a level with the lower border of the same cartilage, but the latter lies nearer to the median plane. Thus the orifice of the pulmonary artery, which arises from the right ventricle, is situated to the left side of the orifice of the aorta, which arises from the left ventricle. This apparent contradiction is accounted for by the obliquity of the interventricular septum, which slopes backwards and to the right.

The **left atrio-ventricular (mitral) orifice** is placed behind the left half of the sternum, opposite the sternal ends of the third interspace and the fourth costal cartilage, and it is disposed obliquely so that the blood is directed forwards, downwards and to the left as it passes from the atrium into the ventricle. The **right atrio-ventricular (tricuspid) orifice** lies behind the right half of the sternum opposite the fourth cartilage, the fourth interspace and the fifth cartilage.

The accurate topography of the valves themselves is not of very great importance in auscultation, as they are placed so close to one another that, on auscultation directly over them, it may be impossible to decide at which orifice a particular sound is produced. On this account, the sounds produced by the closing of the valves are ausculted over areas which are widely separated from one another, and which are placed over the chamber or vessel connected with the valve in question.

The **pulmonary area** lies behind the sternal end of the left second interspace, and in this situation the pulmonary artery is separated from the surface only by the thin anterior border of the left lung. The **aortic area** lies over the right second

costal cartilage at its junction with the sternum. This area projects a little to the right of the aorta, but overlaps the vessel at the point where it approaches most nearly to the anterior surface of the body. The **tricuspid area**, which is placed at the lower extremity of the sternum, is situated over that part of the right ventricle which is most remote from the other orifices. The **bicuspid (mitral) area** lies over the apex of the heart. In this position the left ventricle is very near the surface of the body, and the area itself is as far as possible from the other orifices.

The Action of the Heart.—The rhythmical contractions of the heart begin in the atria at the orifices of the great veins. During atrial contraction the pressure in the ventricles under normal conditions is less than the pressure in the veins, and so the blood is forced into the ventricles. As the ventricles become filled, the cusps of the atrio-ventricular valves are floated upwards towards the orifices which they guard. **Atrial systole** is at once followed by **ventricular systole** and, as the intra-atrial pressure is less than the intra-arterial pressure, the force of the contractions tends to drive the cusps up into the atria. At the same time the papillary muscles contract and, through the chordæ tendineæ, retain the valve in place at the orifice. A brief period of rest, termed the **cardiac diastole**, follows the ventricular contraction, and then the cycle begins again.

The two principal **heart sounds** which are heard on auscultation are produced by the closure of the atrio-ventricular and the semilunar valves. The atrio-ventricular valves close at the commencement of ventricular systole, and, therefore, sounds which are produced during atrial systole will be heard immediately prior to the first sound, *e.g.*, the bruit of bicuspid or tricuspid obstruction. The semilunar valves, which guard the orifices of the aorta and pulmonary artery, close at the end of ventricular systole, and the bruits produced by regurgitation of blood through the aortic or pulmonary orifices occur at the commencement of diastole.

Ventricular systole causes a rise in the arterial blood-pressure which is marked in the **sphygmographic tracing** by the sudden upstroke (Fig. 107). At the end of ventricular systole, the semilunar valves close and the pressure begins to fall. But, as the valves close, the blood endeavours to pass back into the ventricles and it rebounds from the valves, causing a secondary increase in pressure, which is recorded on the tracing as the dicrotic wave. Thereafter the arterial pressure continues to fall during diastole and atrial systole.

The orifices of the superior and inferior venæ cavæ are devoid of competent valves, and therefore a wave of increased pressure passes back along them with each atrial contraction. No valves are found in the superior vena cava or in the in-

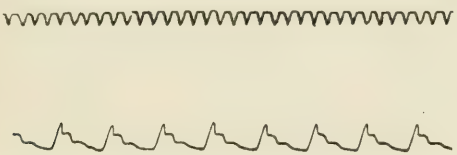


FIG. 107.—Sphygmographic Tracing of a Normal Pulse.

nominate veins (p. 314), which form it, and so the impulse is transmitted to the subclavian and the internal jugular veins (p. 315). About 1 inch above the sternal end of the clavicle, the internal jugular possesses a valve of two crescentic cusps (Fig. 108), which is almost invariably competent. The portion of the vein below the valve is termed the **jugular bulb**, and, since it lies behind the interval between the sternal and the clavicular heads of the sterno-mastoid, it is readily accessible to the receiver of the sphygmo-manometer. This venous pulsation is perfectly normal, and tracings of it are of value in determining the condition of the heart (p. 311).

The subclavian vein, which lies behind the clavicle and is consequently inaccessible, possesses no valves up to a point just distal to its reception of the external jugular vein. There-

after, valves occur at intervals in the subclavian, axillary, and other veins of the upper limb.

The external jugular vein, as a general rule, possesses a competent valve as it crosses the sterno-mastoid muscle. Since no valves intervene between this point and the right atrium (Fig. 108), venous pulsation may, under favourable conditions, be observed in the external jugular of a perfectly healthy subject.

Development of the Heart.—In the young embryo, the

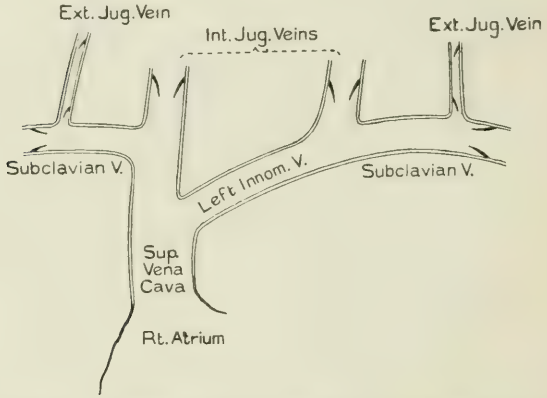


Fig. 108.—Diagram to show the positions of the valves on the tributaries of the Superior Vena Cava.

heart consists of a contractile tube, which is separated into different parts by circular constrictions (Fig. 109). The large veins open into the **sinus venosus**, which is placed at the caudal (or posterior) end of the tube, and it pumps the blood headwards into the **atrium**. The **ventricle** lies in front of the atrium and conveys the blood to the **truncus arteriosus**, which is the most cephalad, or anterior, part of the primitive tubular heart. At this period of development, the heart receives its nerve-supply from the sympathetic system, and as a result the adult atria are supplied from a lower segment of the spinal

medulla than the adult ventricles, for the alteration in their relative positions occurs after the nerve-supply has been acquired.

As the tubular heart grows in size, it becomes bent so that the atrial part passes forwards (*i.e.* towards the head) dorsal to the ventricular part. About this time, the single atrio-ventricular orifice becomes divided into two by the union of two endocardial cushions which project inwards from its margins. At the same time, septa appear in the atrium and in the ventricle and grow towards the linear partition which

FIG. 109.—Diagram of the primitive tubular Heart of the Embryo.

A. Sinus venosus. *C*. Ventricle.
B. Atrium. *D*. Bulbus cordis.

separates the two atrio-ventricular orifices. Before the inter-atrial septum reaches the partition, it breaks down near its centre to form the **foramen ovale**, which remains patent till the end of fœtal life. The uppermost part of the inter-ventricular septum is the last part to form, and, consequently, is the commonest site for an abnormal communication between the two ventricles. This anomaly, however, is extremely rare. While the interventricular septum is in process of formation, a spiral septum arises which subdivides the truncus arteriosus into the aorta and the pulmonary artery. Owing to the fact that these two arteries are derived by subdivision from a

common trunk, in the adult they remain enveloped by the same tubular sheath of serous pericardium (p. 288).

The Circulation in the Fœtus.—The chambers of the fœtal heart communicate with precisely the same blood-vessels as they do in the adult, but these vessels have, in some instances, rather different duties to perform.

The pure blood returns from the placenta by the **umbilical vein**, which joins the left branch of the portal vein (Fig. 110), and, if there were no "short circuit," it would require to pass through the liver before reaching the heart. A certain amount of the pure blood does enter the liver, and this fact accounts for the large size of that viscus in the new-born child. A "short circuit," however, is established by the **ductus venosus**, which connects the left branch of the portal vein to the inferior vena cava. In this way most of the pure placental blood passes directly from the umbilical vein to the inferior vena cava, where it becomes mixed with the impure blood returning from the abdomen and lower limbs.

Thus the purest blood which enters the fœtal heart is poured into the right atrium (auricle) by the inferior vena cava. As it enters the atrium the blood-stream is directed by a fold of endocardium towards the foramen ovale in the inter-atrial septum, through which it passes to reach the left side of the heart. On the other hand, the impure blood carried by the superior vena cava is directed through the right atrio-ventricular orifice into the right ventricle.

The purest blood which the fœtal heart distributes is pumped out by the left ventricle into the aorta, by which it is conveyed to the heart-muscle, the upper limbs, the head, neck and brain.

Since the lungs of the fœtus do not function, it is only necessary that they should be provided with sufficient blood for their own nourishment, but, despite this, the main stem of the pulmonary artery is so large that it does not require to dilate when the lungs become expanded by respiration. The surplus blood from the pulmonary artery passes into the aorta through a communication termed the **ductus arteriosus**.

It is clear, therefore, that the abdominal viscera (with the exception of the liver) and the lower limbs will not be so well nourished at birth as the upper portion of the body.

The **hypogastric arteries**, which arise from the common

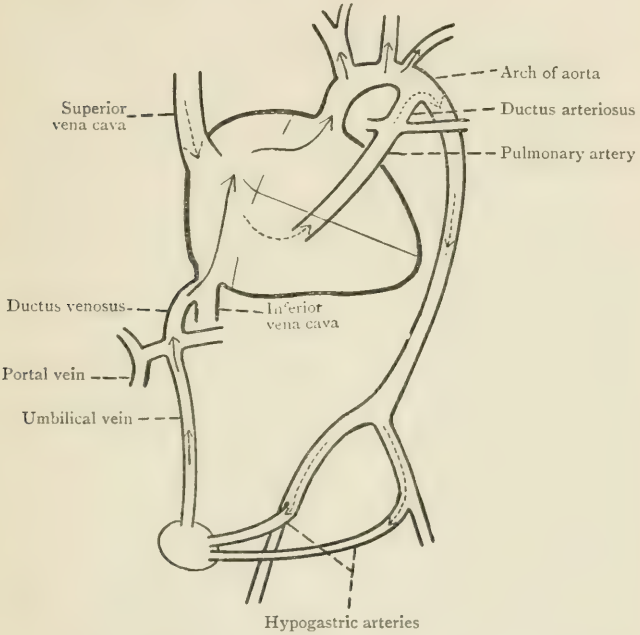


FIG. 110.—Diagram to illustrate the Fœtal Circulation.

The course of the pure blood is indicated by the plain arrows; the dotted arrows indicate the course of the impure or mixed blood.

iliacs, pass up the anterior abdominal wall and enter the umbilical cord. They convey impure blood to the placenta from which it is returned, after being purified, by the umbilica vein. It may be noted that the umbilical cord contains two arteries but only one vein.

Several important changes occur at birth. The expansion

of the lungs with respiration determines the flow of a larger quantity of blood to the lungs and causes an increased blood-pressure within the pulmonary artery, which drags on the ductus arteriosus. The latter is rendered oblique and soon becomes a fibrous cord, termed the ligamentum arteriosum. At the same time the foramen ovale closes, so that all direct communication between the right and left sides of the heart is cut off.

After the ligature and division of the umbilical cord, the blood in the umbilical vein, from the umbilicus to the left branch of the portal vein, undergoes coagulation and the vessel itself becomes converted into a fibrous cord, termed the ligamentum teres of the liver (p. 260). The ductus venosus becomes transformed in a similar manner, but the cause of this change is by no means clear. It has been suggested that icterus neonatorum may be due to patency of the ductus venosus.

Congenital Anomalies of the Heart. — **Congenital absence of the heart** occurs in acardiac monsters, but the condition is of little interest to the clinician as it is never consistent with life.

Dextro-cardia, or complete transposition of the heart, may be associated with a similar transposition of the abdominal viscera, and is always associated with transposition of the great vessels.

Patency of the foramen ovale may occur without producing any characteristic signs. In these cases the opening, which is slit-like in character, is usually of small size, and, as it is provided with a valve-like arrangement, it possesses no clinical significance. A patent foramen ovale may, however, be associated with other cardiac defects, such as imperfections of the upper part of the interventricular septum and patency of the ductus arteriosus. Although the child may be markedly cyanosed and loud heart murmurs may be present, there is seldom any enlargement of the left side of the heart and there may be little increase in the cardiac dulness to the right of the sternum.

Patency of the ductus arteriosus may occur alone. In this case much of the blood which was intended for the lungs is carried off by the ductus into the aortic system, so that there is diminished oxygenation, and, as a result, well-marked cyanosis is present. A loud bruit, systolic in time, is heard all over the præcordia, but its point of maximum intensity is situated behind the left half of the sternum opposite the second intercostal space, *i.e.* over the pulmonary artery. The condition may be distinguished from acquired aortic stenosis by the complete absence of any enlargement of the left ventricle.

Congenital anomalies of the cardiac valves occur with much greater frequency on the right than on the left side of the heart, and the cusps of the semilunar valves are more commonly affected than those of the tricuspid valve. The cusps may be increased to four or five in number or decreased to two, but the condition is of no moment unless accompanied by **stenosis of the pulmonary orifice.** The latter condition is the commonest variety of congenital heart lesion which is met with in practice, and it is marked by three cardinal signs—(*a*) Cyanosis; (*b*) a loud systolic murmur with a weak second sound in the pulmonary area; (*c*) enlargement of the right side of the heart. In many of these cases, the diminished flow of blood to the lungs determines the onset of pulmonary tuberculosis.

Nerve-supply of the Heart.—The nerves which supply the heart are derived from the **sympathetic system** and from the **vagi**, through the superficial and deep cardiac plexuses. The sympathetic nerves have their centres in the spinal medulla in the upper four thoracic segments, and they pass into the upper four thoracic ganglia of the sympathetic in the white rami communicantes. They then ascend into the cervical portion of the sympathetic trunk and are given off as the cardiac branches of the cervical ganglia. The somewhat circuitous course which these fibres take is explained by the fact that, at the period when the heart receives its nerve-supply, it is situated in the cervical region.

The **Superficial Cardiac Plexus** is placed immediately below

the arch of the aorta, and it is formed by the union of a cardiac branch from the left vagus with a cardiac branch from the left sympathetic. A small ganglion is situated at the point where the two nerves unite and it is believed to control the rhythmical contractions of the heart, subject to the influence of stimuli from the higher centres.

It should be observed that the superficial cardiac plexus is formed by branches from the vagus and the sympathetic, *of the left side only*. This arrangement may possibly account for the fact that the referred pains of angina pectoris are usually limited to the left side of the body.

The **Deep Cardiac Plexus** lies in front of the bifurcation of the trachea and it is formed by branches from the sympathetic and the vagi, of both sides of the body.

The fibres derived from the vagus are both afferent and efferent, the latter constituting the **inhibitory** nerves of the heart. Irritation of the vagus causes a slowing of the heart-rate, while paralysis leads to increased rapidity, since the sympathetic accelerator fibres are then no longer opposed.

The sympathetic fibres also are both afferent and efferent, the latter constituting the **accelerator** nerves of the heart. In fracture-dislocation of the vertebral column in the lower cervical region, the sympathetic trunks are completely paralysed (p. 189), while the vagi are not affected. In this condition, therefore, there is usually a definite slowing of the heart-rate.

Cardiac Pain.—When painful symptoms accompany cardiac disturbances they are usually severe and often agonising in character. In the majority of cases of angina pectoris, the pain is experienced at first in the præcordial region. It is at present impossible to decide whether the intense pain which is felt over the heart is actually experienced in the viscus, or whether, as Mackenzie holds, it is experienced in the sensitive tissues of the chest wall. In any case the pain is felt in the areas supplied by the upper intercostal nerves, and, since the sympathetic fibres which supply the heart are derived from

the upper four thoracic segments, it is in these areas that referred pains might be expected to occur in cardiac disturbances.

In later attacks of angina pectoris, the pain tends to radiate from the præcordia down the medial side of the left arm, and, in this case, there is no doubt that the condition exemplifies the viscero-sensory reflex (p. 192), since the painful areas are innervated by the first and second thoracic nerves (Fig. 67).

If a "focus of irritation" (p. 195) is established in the upper thoracic segments of the spinal medulla, areas of cutaneous hyperalgesia (p. 195) may be found in the regions supplied by the nerves arising from the segments affected. In the same way, the muscles supplied by these segments may be very tender on deep pressure, and this muscular hyperalgesia is observed best in the pectoralis major and minor, which receive branches from the first thoracic nerve through the medial anterior thoracic nerves. In some cases where an area of cutaneous hyperalgesia is present, it is possible to induce a severe attack of cardiac pain by such a simple peripheral stimulus as lightly stroking the hyperæsthetic area.

The posterior rami (primary divisions) of the upper thoracic nerves are much less frequently the site of referred cardiac pain than are the anterior rami. In angina pectoris, however, it is sometimes possible to demonstrate areas of hyperæsthesia or hyperalgesia over the spines of the upper four thoracic vertebræ or in the adjoining region.

Afferent impulses from the heart travel not only by the sympathetic but also by the vagus, and it is, therefore, possible for a "focus of irritation" to arise in the medulla oblongata in cardiac disturbances. The sensory nucleus of the vagus is practically continuous with the posterior column of grey matter in the spinal medulla, and a "focus of irritation" may spread downwards and cause an increased excitability of the sensory nerve-cells in the upper cervical segments. In angina pectoris, the pain may radiate into the left side of the neck and involve the areas supplied by the cutaneous branches of

the second, third and fourth cervical nerves (Fig. 69). It is probable that in these cases the stimuli reach the upper part of the spinal medulla by a downward spread from the lower extremity of the sensory nucleus of the vagus. Under these circumstances, the sterno-mastoid and the upper part of the trapezius are usually found to be tender to the touch, for these muscles, although receiving their motor supply from the accessory nerve, receive sensory branches from the cervical plexus (p. 128).

The Cardiac Blood-vessels.—The heart is supplied by the right and left coronary arteries, which arise from the aortic sinuses (p. 318). The orifices of these vessels are so situated that the blood may have difficulty in entering them in atheromatous changes in the wall of the aorta near its origin or in the degenerative changes of the aortic valve which lead to aortic stenosis. Under these conditions, the muscular wall of the heart undergoes degeneration and the circulatory disturbance becomes more pronounced on that account.

The veins of the heart join the coronary sinus, which pours its blood into the right atrium (auricle).

The Musculature of the Heart.—The muscular fibres of the atria (auricles) pass uninterruptedly from the one atrium to the other, but, with the exception of the **atrio-ventricular bundle (of His)**, they do not become continuous with the muscular fibres of the ventricular walls. Both atrial and ventricular fibres are attached to the fibrous rings which bound the atrio-ventricular orifices and constitute what Keith has termed the atrio-ventricular base of the heart.

The primitive tubular heart of the embryo is so altered by the flexures which it undergoes that the atrio-ventricular orifices become placed side by side with the arterial orifices, and not, as in the embryo, at opposite ends of the ventricle. Keith believes that, as a result of these changes, the ventricular muscle fibres are so arranged that, when the ventricle contracts, the distance of the ventricular apex from the "aortic base" (arterial orifices) is unaltered, whereas its distance from the

atrio-ventricular base is definitely diminished. It follows that during ventricular contraction the apex may be regarded as a fixed point, although it moves upwards somewhat and presses against the anterior wall of the chest. On the other hand, the atrio-ventricular base, which constitutes the insertion of both the atrial and the ventricular fibres, moves with each atrial and with each ventricular contraction. As the orifices of the great veins are to be regarded as fixed points, the capacity of the atria becomes diminished with each atrial contraction. Ventricular systole pulls the atrio-ventricular base towards the apex and so increases the atrial capacity.

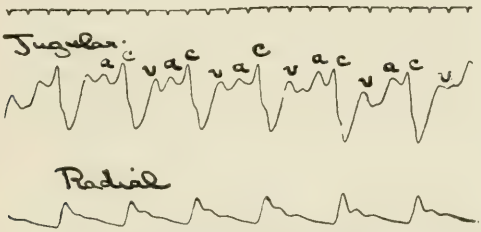


FIG. 111.—Tracing of the Normal Venous Pulse, together with a Synchronous Tracing of the Radial Pulse.

The waves, *v*, *a*, and *c*, are referred to in the text.

During diastole the atrio-ventricular base assumes a position of rest, mid-way between the positions which it occupies during atrial and ventricular contractions, respectively.

This theory of the action of the cardiac musculature can be applied to the interpretation of the **venous pulse.** Atrial contraction causes a rise in the intra-atrial blood-pressure and prevents, for the time being, any further outflow from the veins. This condition is indicated by the upstroke of the venous pulse tracing (Fig. 111, *a*). The ensuing ventricular systole is marked on the tracing by the wave *c*. This does not indicate a true rise in the intra-venous blood-pressure but is transmitted from the common carotid artery. It is suc-

ceeded by a marked fall in the pressure, since, during ventricular systole, the atrial walls are relaxed and the atrial capacity is further increased by the movement of the atrio-ventricular base towards the apex. The filling up of the atrium causes a rise in the intra-venous blood-pressure which is accentuated by the return of the atrio-ventricular base to the position of rest at the end of ventricular systole. The phase ceases when the tricuspid valve opens (Fig. 111, *v*) and it is succeeded by atrial systole. This description only refers to the character of the venous pulse so long as the tricuspid valve is competent.

In **tricuspid incompetence**, the right atrium has to deal with a larger quantity of blood and the pressure during atrial systole therefore rises to a higher level. Ventricular systole is accompanied by a fall in the pressure, but the succeeding secondary rise is hastened in its occurrence by the regurgitation into the atrium. Further, the fall in the secondary wave is less marked, as blood passes from the atrium into the ventricle during the whole of the diastolic period. This variety is referred to as the *ventricular type of venous pulse.*

The Heart Rhythm.—In the primitive tubular heart, the rhythmical waves of contraction begin at the sinus venosus and pass to the atrium and ventricle by direct continuity of muscle fibres. In the adult heart the sinus venosus is incorporated in the atria and most of the muscle fibres are interrupted at the atrio-ventricular base. It is believed that atrial contraction begins near the orifice of the superior vena cava in a specialised area, with distinctive histological characters, which has been termed the **sino-atrial node**. The wave of contraction passes by muscular continuity to the left atrium and it reaches a second specialised area, termed the **atrio-ventricular node**, which is situated on the inter-atrial septum near the atrio-ventricular base. From this node the **atrio-ventricular bundle (of His)**, which is a collection of specialised muscle fibres, takes its origin, and it extends across the atrio-ventricular base into the interventricular

septum. It lies in that part of the septum which is covered by the posterior, or septal, cusp of the mitral valve, and, finally, divides into two parts, one for each ventricle. The exact destination of the terminal fibres is relatively unimportant.

Under normal conditions the rhythmical contractions of the heart begin at the sino-atrial node, and, during atrial systole, they reach the atrio-ventricular node. From there the stimulus is conveyed along the atrio-ventricular bundle and causes ventricular systole. Each atrial systole is therefore

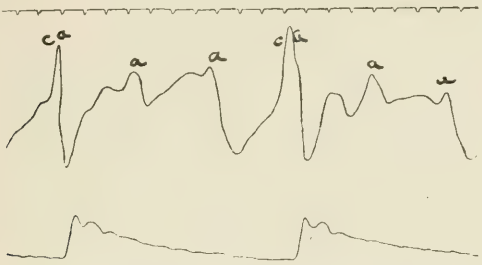


FIG. 112.—Tracings from a case of Complete Heart-Block.

The waves, *a*, correspond to the atrial contractions; the waves, *c*, correspond to the ventricular contractions, as shown by the tracing from the radial pulse.

followed immediately by a ventricular systole, so long as the conducting medium is able to perform its duty efficiently. Pathological lesions of the atrio-ventricular bundle may diminish its conductivity, and as a result each atrial systole is not immediately followed by a ventricular systole. In these cases, however, a summation of stimuli produces the effect which a single stimulus is insufficient to produce, and a ventricular systole follows every second or every third atrial contraction. This condition is known as **Heart-block**. A small lesion, involving the atrio-ventricular bundle before it divides, may cause complete heart-block, but a much larger lesion, involving one of its divisions, may give rise only to

partial heart-block, or may produce no alteration at all in the heart rhythm.

Although the heart rhythm normally commences at the sino-atrial node and is conveyed to the ventricle by the atrio-ventricular bundle, a complete lesion of the latter does not necessarily involve cessation of the ventricular contractions. Under these circumstances, ventricular contractions continue but they acquire a rhythm of their own, which is slower than, and quite distinct from, the atrial rhythm. Pulse tracings of this condition show that a ventricular contraction does not necessarily succeed an atrial contraction, but the two may occasionally be synchronous or the ventricular systole may precede the atrial systole.

The Great Vessels

The **Superior Vena Cava** is formed by the union of the right and left innominate veins, which unite with one another behind the sternal end of the first right costal cartilage. It descends, partly behind the sternum and partly projecting beyond its right border, to terminate in the uppermost part of the right atrium. Below the second costal cartilage, the vena cava is enclosed within the fibrous pericardium and it is related anteriorly to the serous pericardial sac. When the dulness to percussion produced by a pericardial effusion extends upwards into the right second intercostal space, the superior vena cava is usually compressed and the veins of the head, neck and upper limbs become greatly engorged. A similar condition is met with when the vena cava is compressed by an aneurism of the ascending aorta, which lies to its left side and on a slightly anterior plane. Such an aneurism may not only compress the vena cava but may subsequently rupture into it, giving rise to an arterio-venous aneurism, which is indicated by a sudden great increase in the already existing venous engorgement.

The **Innominate Vein** is formed behind the sternal end of

the clavicle by the union of the internal jugular and subclavian veins. On the *right side* it descends vertically on the medial aspect of the apex of the right lung. It is only 1 inch in length and, therefore, it is rarely involved alone, as tumours which are of sufficient size to compress it are also large enough to affect the left innominate vein, either directly or indirectly through the superior vena cava.

The *left innominate vein* passes to the right and downwards behind the upper half of the manubrium. It is about 3 inches long, and is consequently more exposed to pressure than the corresponding vein of the right side. In its course, it crosses the left subclavian, the left carotid and the innominate arteries close to their origin from the aortic arch, and it may therefore be compressed by aneurisms affecting this part of the aorta or the branches mentioned. It is placed behind the remains of the thymus, and it is characteristic of mediastinal tumours which originate from this developmental remnant that their pressure symptoms are first discovered in the engorgement of the veins of the left upper limb and the left side of the head and neck.

The absence of valves from the superior vena cava and the innominate veins, and the venous jugular pulse, which is thus rendered possible, are referred to on page 301.

The **Inferior Vena Cava** is formed at the right side of the fifth lumbar vertebra by the union of the two common iliac veins, which return the blood from the lower limbs and the pelvis. It ascends through the abdomen behind the peritoneum on the posterior abdominal wall, and, in its lower part, it is related anteriorly to the root of the mesentery (p. 240) and the coils of the small intestine. Opposite the third lumbar vertebra, the inferior vena cava is crossed by the third portion of the duodenum and, immediately above this level, it lies behind the head of the pancreas. In the latter situation, the vena cava may be compressed against the vertebral column by malignant tumours of the gland. Above the pancreas, the vena cava passes successively behind the first portion of the

duodenum, the epiploic foramen (of Winslow) and the liver. It pierces the diaphragm opposite the fibro-cartilage between the eighth and ninth thoracic vertebræ and at once enters the lowest part of the right atrium (auricle) of the heart.

As it ascends through the abdomen, the inferior vena cava receives numerous tributaries. Below the head of the pancreas, it is joined by the lower lumbar and the right spermatic (or ovarian) veins. As it lies behind the head of the pancreas, it receives both renal veins and, just before it pierces the diaphragm, it receives the right and left hepatic veins.

The signs produced by **obstruction of the inferior vena cava** vary according to the site of the obstruction. When it is compressed near its origin, there may be little or no ascites and the venous stasis is most evident in the lower limbs. Swelling of the feet and ankles and dilatation of the superficial veins of the leg are always present. When the obstruction is very great, an effort is made to bring about compensation by the establishment of a new channel of return to the heart. The superficial veins of the lower part of the anterior abdominal wall pour their blood into the femoral vein, and so it ultimately reaches the inferior vena cava. On the other hand, the veins from the upper part of the anterior abdominal wall pour their blood into the intercostal and lateral thoracic veins, which are ultimately tributaries of the superior vena cava. These two groups communicate freely with one another, and, as they are devoid of valves and as the loose superficial fascia in which they lie permits of a large degree of dilatation, the anastomosing channels become greatly enlarged when the inferior vena cava is obstructed. In this condition, therefore, it is usually found that the superficial veins of the abdominal and thoracic walls are enormously dilated. The condition is somewhat similar to the "Caput Medusæ" appearance found in portal obstruction (p. 276), but presents this essential difference that, whereas in portal obstruction the blood-flow radiates in both directions from the umbilicus, in obstruction of the inferior

vena cava the direction of the blood-stream is upwards only, towards the superior vena caval system.

The hepatic veins, which are the last tributaries received by the inferior vena cava, return the blood conveyed to the liver both by the hepatic artery and by the portal vein (p. 261). Regurgitation of blood into the inferior vena cava from the right atrium will therefore produce not only the signs of vena caval obstruction but also the signs of portal obstruction. In this condition the effects are first to be observed in the liver, owing to the retardation of the outflow from the hepatic veins. The organ becomes greatly distended and projects downwards considerably beyond the costal margin. On palpation, pulsations are readily detected and, when they are carefully examined, they are found to occur just before the apex-beat. Tracings of the hepatic pulse correspond precisely to tracings of the jugular pulse, because they are both produced in the same way.

Unless the right atrium recovers its tone, other signs of vena caval obstruction follow dilatation of the liver. Owing to the retardation of the outflow through the renal veins and the consequent disturbance of the functions of the kidneys, the urine is scanty in quantity and contains albumen. The general venous congestion leads to an increased transudation of serum into the peritoneal sac and, as the stomata (p. 240) are unable to carry it away with sufficient rapidity, the condition of ascites develops.

The **Pulmonary Veins** convey the oxygenated blood from the lungs to the left atrium. There are usually two on each side, but they may unite to form a common trunk before entering the heart. Dilatation of the left atrium (auricle) retards the outflow from the pulmonary veins, and, as a result of the venous congestion within the lung, an increased transudation of serum occurs into the pleural sacs. As this variety of hydrothorax is not inflammatory in origin, the fluid in most cases is not limited by adhesions, and it therefore gravitates down to the lowest recesses of the pleural sacs.

Owing to the cardiac condition, the patient is usually in the dorsal decubitus or else in the semi-sitting posture, and the fluid therefore accumulates in the lower limit of the pleural sac posteriorly.

The **Ascending Aorta** begins at the aortic orifice of the left ventricle and passes upwards, slightly forwards and to the right. Throughout its course it lies entirely behind the sternum and it approaches most nearly to the anterior surface of the body at its termination, which lies behind the right half of the sternum opposite the second costal cartilage. As the blood enters the ascending aorta from the left ventricle, it impinges on its right wall, and, as a result of this continually recurring pressure, the vessel is rendered oval instead of circular on transverse section. There is thus a normal dilatation, which, under certain circumstances, may become increased so as to constitute a pathological condition.

Anteriorly, the ascending aorta is covered by the thin anterior borders of both lungs. When it is the site of aneurismal dilatation, it compresses the right lung and projects beyond the right border of the sternum. In this case, visible pulsations may be present in the right second intercostal space and the aortic sounds are heard with maximum intensity in that situation. As it bulges to the right, the ascending aorta may not only compress the right lung but also the superior vena cava, which lies along its right side and on a slightly posterior plane (Fig. 105).

Close to its origin, the aortic wall presents three small dilatations, which are termed the **aortic sinuses (of Valsalva)**. Each sinus is situated opposite a cusp of the aortic valve, and the right and left coronary arteries arise from the anterior and left posterior sinuses, respectively (p. 310).

The **Arch of the Aorta** commences at the termination of the ascending aorta and, arching upwards, backwards and to the left, it reaches the left side of the body of the fourth thoracic vertebra, where it becomes continuous with the descending thoracic aorta. The backward inclination of the

arch is much more pronounced than its inclination to the left, and, as a result, almost the whole of the vessel lies behind the manubrium sterni (Fig. 106).

At its commencement, the aortic arch occupies the interval between the two pleural sacs, but, in most of its course, it is covered by the left mediastinal pleura. As the left vagus and phrenic nerves descend through the thorax, they cross the vessel and intervene between it and the pleural sac. The left innominate vein crosses the branches of the aortic arch close to their origins, and it is therefore closely related to the upper border of the arch.

The signs produced by an **aneurism of the aortic arch** depend partly on the direction in which it enlarges. When it does so in a *forward* direction, it compresses the left lung and comes into contact with the manubrium. The area of superficial dulness in this region becomes increased in size, and, as the aneurism enlarges, it may erode the sternum. At an early stage, however, it may be difficult to determine whether the dulness is due to aneurism or to a mediastinal tumour. The left vagus and phrenic nerves are more liable to be stretched than to be compressed, but they usually slip backwards over the aneurism, and their involvement can rarely be determined from the physical signs.

Posteriorly, the aortic arch comes into contact successively with the trachea, the left recurrent nerve, the œsophagus, the thoracic duct and the vertebral column (Fig. 113). Any or all of these structures may be compressed, when an aneurism of the aortic arch enlarges in a *backward* direction. Pressure on the trachea results in respiratory discomfort and is indicated by the association of râles with the breath sounds. This sign may be accompanied by difficulty in swallowing, since the œsophagus passes downwards between the trachea and the vertebral column. The left recurrent nerve leaves the vagus at the lower border of the arch and hooks backwards and upwards behind the vessel to gain the groove between the trachea and the œsophagus. It is very commonly affected in

aneurisms of this part of the aorta and its compression is followed, in the first instance, by an abductor paralysis of the left vocal fold (true vocal cord, p. 338), which produces

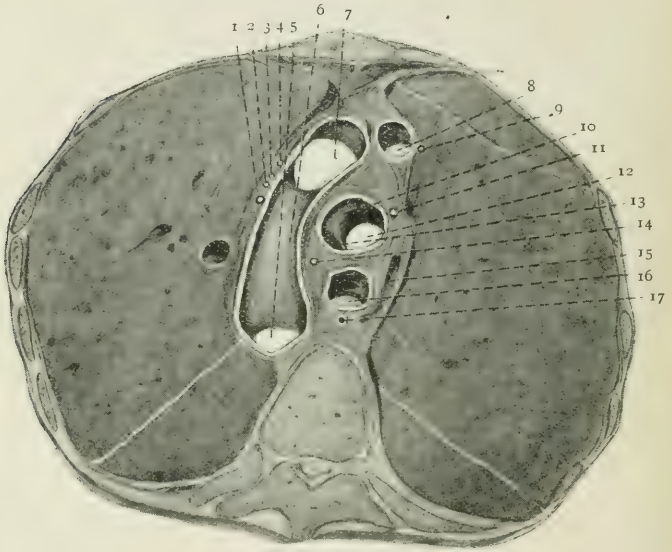


FIG. 113.—Transverse Section through the Thorax at the level of the fourth thoracic vertebra.

1. Left vagus nerve.
2. Cardiac branch of sympathetic.
3. Cardiac branch of vagus.
4. Left phrenic nerve.
5. Descending aorta.
6. Aortic arch.
7. Ascending aorta.
8. Superior vena cava.
9. Right phrenic nerve.
10. Trachea.
11. Right vagus nerve.
12. Right bronchus.
13. Ridge indicating bifurcation of trachea.
14. Left recurrent (laryngeal) nerve.
15. Vena azygos.
16. Œsophagus.
17. Thoracic duct.

strident breathing and a loud "brassy" note on coughing. At a later stage the fold may be completely paralysed. This condition is characterised by the toneless character of the voice (*vox anserina*) and by inability to cough in an efficient manner.

Pressure on the thoracic duct is not easy to recognise, as the communications which it establishes with the right lymphatic trunk (p. 324) may dilate sufficiently to compensate for the obstruction.

When the aneurism enlarges in an upward and backward direction, it may exert pressure on the upper part of the left sympathetic trunk (Fig. 49). As a result, the left pupil becomes, at first, dilated and, later, contracted (p. 189).

Erosion of the vertebral bodies is by no means uncommon, and the condition is accompanied by the characteristic pain of bone affections. Enlargement in a backward direction may bring the aneurism into relation with the intercostal nerves, as they pass forwards and laterally from the intervertebral foramina. The nature of the pain in this case is quite distinctive. It is radiating in character, and is referred to the peripheral distribution of the anterior and lateral cutaneous branches.

As the aortic arch passes backwards, it lies above the root of the left lung. Each pulsation of an aneurism of this part of the aorta thrusts the left bronchus in a downward direction, and this fact helps to account for the production of "tracheal tugging" (p. 288).

Enlargement in an upward and forward direction will cause pressure on the left innominate vein with consequent venous engorgement of the left half of the head and neck and of the left upper limb.

From the convex upper border of the aortic arch, three large branches arise, namely, the innominate, the left common carotid and the left subclavian arteries.

The **Innominate Artery** arises in the median plane and passes upwards and to the right, on the anterior surface of the trachea, to terminate behind the right sterno-clavicular articulation, where it divides into the right subclavian and common carotid arteries. The relationship of this artery to the jugular (suprasternal) notch is somewhat variable, and, although usually placed at a lower level, it frequently rises so high that its pulsations can easily be felt in that region.

Aneurisms of the innominate artery, and aneurisms of the aortic arch which bulge upwards, also produce pulsations which are palpable and sometimes visible at the upper border of the manubrium sterni.

The **Descending Thoracic Aorta** begins at the left side of the body of the fourth thoracic vertebra and inclines forwards to reach the median plane, so that, as it passes through the diaphragm, it lies in front of the vertebral column. This part of the aorta is closely related to the œsophagus. Above, the œsophagus lies to the right of the aorta and on a slightly anterior plane. As the vessel descends, it inclines medially, and it is crossed by the œsophagus just before it pierces the diaphragm. It is the latter situation which is the usual site of aneurisms of the descending thoracic aorta, and consequently these aneurisms are usually associated with marked difficulty in swallowing.

The **Abdominal Aorta** begins at the aortic opening in the diaphragm and descends in front of the vertebral column. Its terminal bifurcation into the two **common iliac arteries** occurs opposite the left side of the fourth lumbar vertebra and corresponds, on the anterior abdominal wall, to a point a little below and a little to the left of the umbilicus. At first the abdominal aorta lies behind the posterior wall of the omental bursa, and then it descends behind the body of the pancreas, which crosses the vessel at the level of the second lumbar vertebra. Below the pancreas, the aorta is crossed by the third or horizontal portion of the duodenum, and, at a still lower level, it lies immediately behind the peritoneum on the posterior wall of the infra-colic compartment of the abdomen.

In neurasthenic patients with flaccid abdominal walls, the pulsations of the abdominal aorta can be felt with extraordinary distinctness, but under normal conditions very firm deep palpation must be employed, and, even then, it is impossible to determine the character of the pulse. In aneurisms affecting the descending thoracic or the abdominal aorta, complete absence of pulsation in the femoral artery and

its branches is a valuable diagnostic sign when thrombosis has occurred.

Tumours affecting viscera which lie in front of the abdominal aorta may present palpable pulsations. The viscera most commonly involved are—(1) The left lobe of the liver, which lies in front of the descending thoracic aorta, and is separated from it only by the diaphragm; (2) the pylorus, which is separated from the abdominal aorta only by the peritoneal walls of the omental bursa (lesser sac); and (3) the pancreas, which crosses in front of the abdominal aorta. The pulsation in these cases consists of a simple, heaving, forward movement, and is not expansile in character. In this way, it may be distinguished from the pulsation of an aneurism of the abdominal aorta, although it is only when the latter is of fairly large size that the expansile nature of its pulsations can be determined in a satisfactory manner.

Aneurisms of the abdominal aorta usually enlarge in a forward direction, and the tumour which they produce can be palpated through the anterior abdominal wall. In some cases, they enlarge in a backward direction and erode the lumbar vertebræ, ultimately compressing the cauda equina (p. 40) and giving rise to paraplegia.

The **Pulmonary Artery** arises from the right ventricle and passes upwards and backwards. At its origin it is placed in front of the ascending aorta, but it inclines to its left side and terminates below the aortic arch by dividing into right and left branches. At its termination it is placed behind the sternal end of the left second intercostal space, and is separated from the surface only by the thin anterior part of the left lung. When this part of the lung becomes retracted in pulmonary tuberculosis, the pulsations of the pulmonary artery are rendered visible in the left second interspace; or, when it becomes consolidated in phthisis or pneumonia, these pulsations may be transmitted to the surface. In either case, light percussion over the left half of the sternum at this level will demonstrate a decrease in the area of lung resonance.

At its bifurcation, the pulmonary artery is attached to the lower surface of the aortic arch by the ligamentum arteriosum (p. 306).

The **Thoracic Duct** is the largest lymph vessel in the body. It commences on the right side of the vertebral column in a dilatation, termed the **cisterna chyli**, which is situated in the epigastric region. From this origin the thoracic duct ascends into the thorax, where it lies at first behind the œsophagus. In the upper part of the thorax, however, it crosses the median plane and ascends along the left margin of the œsophagus in close contact with the left mediastinal pleura (Fig. 113). In the neck the thoracic duct lies posterior to the left lobe of the thyreoid gland, but, opposite the seventh cervical vertebra, it passes laterally and then downwards and terminates in the angle of union between the left internal jugular and subclavian veins.

The **cisterna chyli** receives the lymph vessels which drain the alimentary canal, and it may, therefore, become infected in cases of intestinal tuberculosis. Some cases of miliary tuberculosis arise in this way.

The Right Lymphatic Duct is a small vessel, which drains the lymph from the right upper limb, the right side of the head and neck, the right half of the thorax and its contents, and the upper surface of the liver. It ends in the angle of union between the right internal jugular and the right subclavian veins.

V

THE RESPIRATORY SYSTEM

The Nose

The **Nasal Septum,** which subdivides the nasal cavity into a right and a left half, is partly osseous and partly cartilaginous. The vomer, which articulates with the sphenoid above and the hard palate below, forms the posterior part of the septum, and its posterior border can be seen on posterior rhinoscopy. Its anterior border articulates above with the perpendicular lamina of the ethmoid, which forms the upper part of the septum, and below with the septal cartilage, which forms the lower part of the septum (Fig. 114).

When the growth of the individual components of the septum is more rapid than the growth of the septum as a whole, the lines of force meet one another along the articulations and *deviation of the septum* results. Osseous deviation occurs at the articulation between the vomer and the ethmoid, but cartilaginous deviation may affect any part of the septal cartilage. The former condition does not arise before the seventh year, as, at an earlier date, ossification has not proceeded far enough to bring the two bones into contact.

On the **Lateral Wall of the Nasal Cavity**, the three *conchæ* (*turbinated bones*) project downwards and medially and subdivide the cavity into an *inferior*, a *middle* and a *superior meatus*. The *inferior concha* forms the roof of the inferior meatus, and, under cover of its anterior extremity, the **naso-lacrimal duct** (p. 208) opens into the nasal cavity. The

posterior extremity of the inferior concha extends almost to the **choanæ (posterior nares)** and can therefore be inspected on *posterior rhinoscopy*. The mucous membrane, which covers it, is very loosely attached to the subjacent bone, and serous effusions into the lax submucous tissue may cause complete

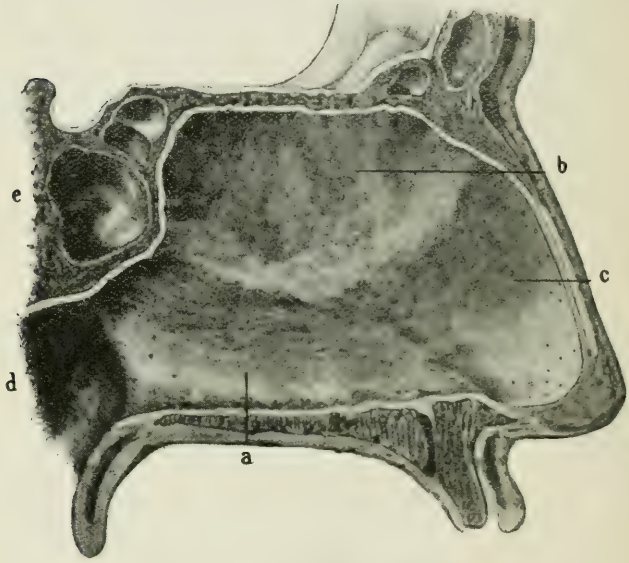


FIG. 114.—The Nasal Septum.

a. Vomer.
b. Perpendicular lamina of ethmoid.
c. Septal cartilage.
d. Naso-pharynx.
e. Sphenoidal air-sinus.

occlusion of the inferior meatus. This condition is found in coryza, chronic posterior hypertrophic rhinitis, etc.

The floor of the inferior meatus, which also constitutes the floor of the nose, is formed by the hard palate and is practically horizontal.

The *middle concha* forms the roof of the middle meatus and projects downwards and medially so as to obscure the orifices

of the air-sinuses which open into it. On the side wall of the middle meatus there is a prominent elevation, termed the *bulla ethmoidalis*, which contains the middle ethmoidal air-sinuses. At the anterior extremity of the bulla, the middle meatus receives the infundibulum of the **frontal sinus**. Below, the bulla is limited by the *hiatus semilunaris*, a groove which receives the openings of the **anterior ethmoidal air-sinuses** anteriorly and the **maxillary sinus** (**antrum of Highmore**) posteriorly. The **middle ethmoidal air-sinuses** open into the middle meatus at the upper border of the bulla ethmoidalis.

The *superior concha* forms the roof of the superior meatus, which receives the openings of the **posterior group of the ethmoidal air-sinuses**. A small recess, termed the *recessus spheno-ethmoidalis*, intervenes between the superior concha and the roof of the nasal cavity and receives the opening of the **sphenoidal air-sinus.**

The air-sinuses which open into the nasal cavity are all lined by muco-periosteum, which is continuous with the mucous membrane of the nose. Owing to the proximity of the various orifices to one another, in the middle meatus especially, septic infection originating in one sinus may readily spread to involve the others.

The outlines of the frontal, maxillary and sphenoidal air-sinuses can all be made out in X-ray photographs, and the condition of the first two can, to some extent, be determined by the process of trans-illumination.

The **Maxillary Sinus** (**Antrum of Highmore**) is placed in the interior of the maxilla. It is present at birth, but does not begin to enlarge until about the seventh year, and after puberty it rapidly increases in size. The orifice by means of which it communicates with the middle meatus is placed high up on its medial wall, and, consequently, when pus collects in the sinus it cannot readily make its escape into the nasal cavity.

The **Frontal Sinuses** are placed in the frontal bone above the root of the nose. They are separated from one another by an osseous septum, which is usually deflected to one or

other side of the median plane. The sinus extends backwards into the orbital part of the frontal bone, and lies immediately below the floor of the anterior part of the anterior cranial fossa. On this account, fractures through this part of the

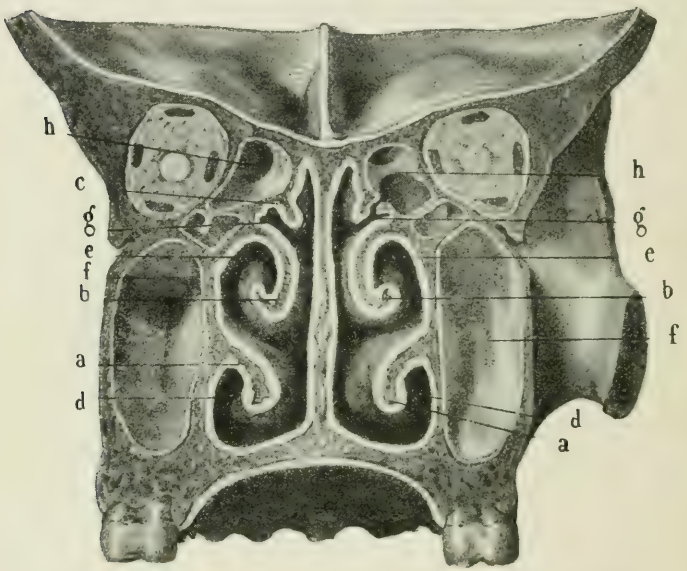


FIG. 115.—Frontal (Coronal) Section through the Skull, showing the nasal fossæ.

a. Inferior concha.
b. Middle concha.
c. Superior concha.
d. Inferior meatus.
e. Middle meatus.
f. Maxillary sinus.
g. Superior meatus.
h. Posterior ethmoidal sinus.

floor of the skull open into the frontal sinus and blood and subdural or even cerebro-spinal fluid may be discharged from the nose.

The frontal sinus does not appear much before the seventh year. At puberty it can be recognised in X-ray photographs, and it attains its maximum size between the ages of 21 and 25.

The Naso-Pharynx

The naso-pharynx lies behind the nasal cavity and constitutes the highest part of the pharynx. In front, it communicates with the nasal cavity through the choanæ (posterior nares), which are each one inch long and half an inch wide. Below, it communicates freely with the oral part of the pharynx, but this communication is closed when the soft palate is raised (p. 97).

The pharyngeal orifice of the **auditory (Eustachian) tube** is situated on the side wall of the naso-pharynx. Behind the orifice, the cartilage which supports the roof and medial wall of the tube forms a distinct prominence, termed the **torus tubarius (Eustachian cushion)**, and this elevation forms the anterior wall of a small pocket of mucous membrane which constitutes the **pharyngeal recess (fossa of Rosenmüller)**.

The auditory tube passes backwards and laterally from the pharynx to the tympanum, and, as it is kept patent by the cartilage in its wall, it affords a channel for the constant renewal of the air in the tympanic cavity (p. 201). When the tube becomes obstructed, the air within the tympanum becomes absorbed and deafness results. Under certain conditions it is desirable to inflate the tympanic cavity, and this operation is conducted through the auditory tube. A Eustachian catheter is passed backwards along the floor of the inferior meatus of the nose until it impinges against the posterior wall of the naso-pharynx. If the instrument is then rotated laterally through 90°, its point will rest in the pharyngeal recess. It is then withdrawn slightly, and the point can be felt to slip over the torus tubarius and enter the pharyngeal orifice of the tube.

The posterior wall of the naso-pharynx contains a small collection of lymphoid tissue, which is termed the **pharyngeal tonsil**. After puberty the pharyngeal tonsil rapidly atrophies, but before that period it may be of considerable size. In children this lymphoid tissue frequently proliferates and gives

rise to the condition of **adenoids**. When the adenoids are extensive, they fill up the nasal part of the pharynx and render nasal breathing impossible. In addition, the pharyngeal orifice of the auditory tube may become occluded, and, consequently, children who suffer from adenoids not only breathe through the mouth but are also dull of hearing.

As the atmospheric air passes through the nasal cavity on its way to the lungs, it absorbs a slight amount of moisture from the nasal mucous membrane and its temperature is slightly raised. These alterations in the character of the air must be brought about also when the patient breathes through the mouth, and, under these circumstances, the air absorbs moisture from the mucous membrane of the tongue, which becomes unpleasantly and unnaturally dry in consequence.

The Larynx

The larynx is kept constantly patent by its cartilaginous walls, and it communicates with the laryngeal part of the pharynx through its superior aperture.

The **thyreoid cartilage** consists of two laminæ which meet in the median plane anteriorly and form the *laryngeal prominence* (*pomum Adami*), which is subcutaneous. The **cricoid cartilage** is shaped like a signet ring. Its narrow anterior part can be felt through the skin 1 inch below the laryngeal prominence, and its deeper posterior part expands to fill up the gap which exists posteriorly between the two laminæ of the thyreoid cartilage (Fig. 116). A small diarthrodial joint exists between the inferior cornu of the thyreoid and the side of the cricoid, and enables the cartilages to be moved, one on the other, by the contraction of the crico-thyreoid muscles (p. 335).

The **arytænoid cartilages**, two in number, articulate with the upper border of the posterior part of the cricoid cartilage. They are pyramidal in shape and their anterior basal angles receive the posterior attachments of the vocal folds (true cords).

The **epiglottis** is a leaf-shaped cartilage and its broad, free, upper portion projects upwards behind the dorsum of the

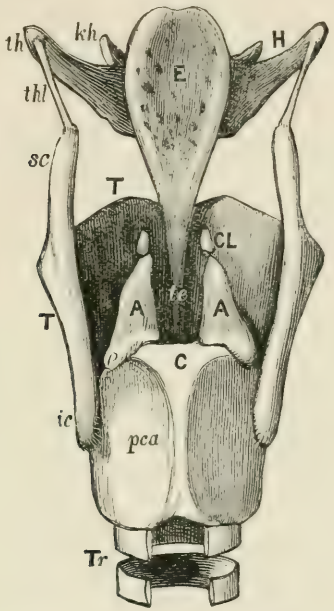


FIG. 116.—Posterior Aspect of the Cartilages of the Larynx. (TURNER'S *Anatomy*.)

A. Arytænoid cartilage.
C. Cricoid cartilage.
CL. Corniculate cartilage.
E. Epiglottis.
H. Hyoid bone.
T. Thyreoid cartilage.
Tr. Trachea.
e. Muscular process of arytænoid cartilage.
i.c. Inferior cornu of thyreoid cartilage.
kh. Lesser cornu of hyoid bone.
p.c.a. Origin of crico-arytænoideus posterior.
s.c. Superior cornu of thyreoid cartilage.
t.e. Thyreo-epiglottic ligament.
t.h. Greater cornu of hyoid bone.
t.h.l. Lateral thyreo-hyoid ligament.

tongue. Its narrow lower end is attached to the thyreoid cartilage.

The **aditus laryngis** (**upper aperture**) is directed backwards

and very slightly upwards towards the laryngeal part of the pharynx (Fig. 117). The direction of this opening must be borne in mind when an intubation tube is being inserted into the larynx. The index finger of the left hand is introduced into the mouth and is carried backwards over the tongue until the upper border of the epiglottis is reached. The intubation tube is then passed in with the right hand and guided along the left index finger. The posterior or laryngeal surface of the epiglottis slopes obliquely forwards and downwards, and the end of the tube is kept in contact with this surface until it enters the upper compartment of the larynx.

The upper aperture of the larynx is bounded laterally by the **ary-epiglottic folds** (Fig. 86). They contain the *ary-epiglottic muscles*, which act as a sphincter of the opening during deglutition. On laryngoscopic examination, two little elevations, separated by a small groove, can be observed in the posterior part of the fold. They are produced by nodules of cartilage which lie in the submucous tissue. The more posterior nodule, which is situated on the apex of the arytænoid, is termed the *corniculate cartilage*, and the more anterior the *cuneiform cartilage*. Occasionally, in tuberculous laryngitis, these elevations become abnormally enlarged and they may hide the interior of the larynx on laryngoscopic examination.

On the lateral side of the ary-epiglottic fold there is a small recess, termed the **recessus piriformis**. The mucous membrane which lines it is supplied with sensation by the internal laryngeal nerve, and when small particles of food become lodged in the recess, they set up an uncontrollable fit of coughing (p. 97).

The **vestibule** of the larynx extends from the aditus to the **ventricular folds** (**false vocal cords**), and, owing to the direction of the aditus, its anterior wall is much longer than its posterior wall. The anterior wall is formed by the epiglottis, which shows, in its lower part, a well-marked convex prominence, termed the **epiglottic tubercle** (**cushion**).

The **ventricular fold (false vocal cord)** consists of a few muscular fibres and a weak ligamentous band, covered with

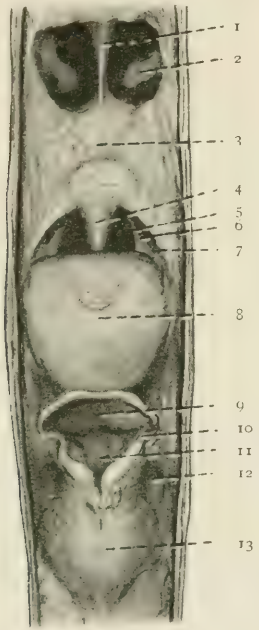


FIG. 117.—The Interior of the Pharynx, viewed from behind, after removal of the posterior pharyngeal wall.

1. Nasal septum.
2. Inferior concha (turbinated bone).
3. Soft palate.
4. Uvula.
5. Glosso-palatine arch (anterior pillar of fauces).
6. Tonsil.
7. Pharyngo-palatine arch (posterior pillar of fauces).
8. Dorsum of tongue.
9. Epiglottis.
10. Ary-epiglottic fold.
11. Upper aperture of larynx.
12. Recessus piriformis.
13. Posterior aspect of cricoid cartilage.

mucous membrane. Anteriorly, the two folds are attached side by side to the thyreoid angle, but they diverge from one another as they pass backwards, bounding the **rima vestibuli**

(**false glottis**). The ventricular folds cannot normally be approximated to one another, but temporary spasm is said to occur and to account for stammering at initial vowels.

The **ventricle of the larynx** is very short; it is bounded

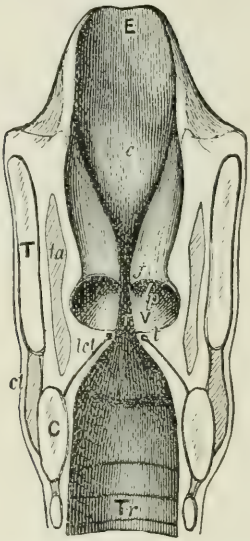


FIG. 118.—Frontal (Coronal) Section through the Larynx. (TURNER'S *Anatomy*.)

E. Epiglottis.
C. Cricoid cartilage.
T. Thyreoid cartilage.
Tr. Trachea.
V. Laryngeal ventricle.
c. Epiglottic tubercle.
ct. Crico-thyreoid muscle.
f. Ventricular fold (false vocal cord).
lct. Conus elasticus (crico-thyreoid membrane).
p. Appendix ventriculi.
r. Rima glottidis.
t. Vocal fold (true vocal cord).
ta. Thyreo-arytænoid muscle.

above by the ventricular folds and below by the vocal folds (true cords).

The **Vocal Fold** consists of a strong fibrous band, termed the *vocal ligament*, which is covered laterally by the *musculus vocalis* and medially by the mucous membrane of the larynx

(Fig. 118). The mucous membrane is tightly bound down to the vocal ligament and, in this situation, it contains very few blood-vessels. On this account the vocal folds are much paler in colour than the surrounding mucous membrane under normal conditions.

In the vestibule and ventricle of the larynx, the mucous membrane is very loosely bound down, except over the epiglottis and the vocal folds. In **œdema glottidis**, serum collects in the loose submucous tissue of the larynx and gravitates downwards. It cannot, however, descend over the vocal folds, and consequently, as it increases in amount, it brings the ventricular folds (false cords) and the walls of the cavity into contact with one another, causing complete obstruction to respiration.

The vocal ligament is attached to the thyreoid angle in front and to the **vocal process** (**anterior basal angle**) of the arytænoid behind. Under favourable conditions, the vocal process can be seen in the posterior part of the vocal fold on laryngoscopic examination.

The **rima glottidis** consists of an *intermembranous part*, placed between the vocal folds, and an *intercartilaginous part*, placed between the vocal processes and the bases of the arytænoid cartilages (Fig. 120). The differentiation into two parts is seen best when the glottis is widely open, as it then assumes a somewhat lanceolate shape. This shape is assumed because the arytænoid cartilages, being unable to separate widely from one another, undergo rotation on the cricoid so that the vocal processes are rotated laterally (Fig. 120).

The **muscles** which act on the vocal folds may be divided into four groups—(a) *Tensors*, (b) *relaxors*, (c) *abductors*, and (d) *adductors*.

(*a*) The **crico-thyreoid** passes backwards and upwards from the side of the cricoid to the thyreoid cartilage. The line of its pull lies in front of the crico-thyreoid joint, and consequently, when the muscle contracts, it tilts the thyreoid cartilage downwards and forwards. As a result, the anterior

attachment of the vocal fold is carried forwards while the posterior attachment remains fixed, and the folds are therefore rendered tense. This muscle is extrinsic in position and is supplied by the *external laryngeal nerve* (p. 97).

(*b*) The **vocalis** and the **thyreo-arytænoid**, which really consists of the superficial fibres of the vocalis, pass from the thyreoid cartilage in front to the lateral surface of the

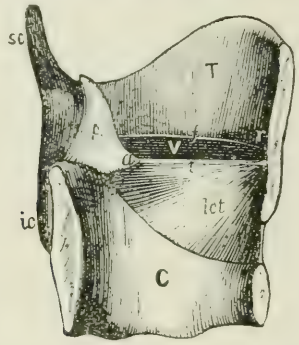


FIG. 119.—The Interior of the Left Half of the Larynx. The mucous membrane and the laryngeal muscles have been removed. (TURNER'S *Anatomy*.)

A. Arytænoid cartilage.
C. Cricoid cartilage.
T. Thyreoid cartilage.
V. Laryngeal ventricle.
a. Vocal process of arytænoid cartilage.
f. Ventricular fold (false vocal cord).
ic. Inferior cornu of thyreoid cartilage.
lct. Conus elasticus (crico-thyreoid membrane).
r. Thyreoid angle.
sc. Superior cornu of thyreoid cartilage.
t. Vocal fold (true vocal cord).

arytænoid behind. Their contraction approximates the two attachments of the vocal folds, which consequently become relaxed.

(*c*) The **crico-arytænoideus posterior** arises from the posterior surface of the cricoid, below, and is inserted into the *muscular process* (*lateral basal angle*) of the arytænoid. Its line of pull lies posterior to the centre of the crico-arytænoid joint, and its contraction, therefore, rotates the arytænoid so

that its vocal process passes laterally and the vocal folds are abducted (Fig. 120).

(*d*) The **crico-arytænoideus lateralis** arises from the antero-lateral surface of the cricoid and passes upwards, backwards and laterally to reach the muscular process of the arytænoid. Since its line of pull is anterior to the centre of the crico-

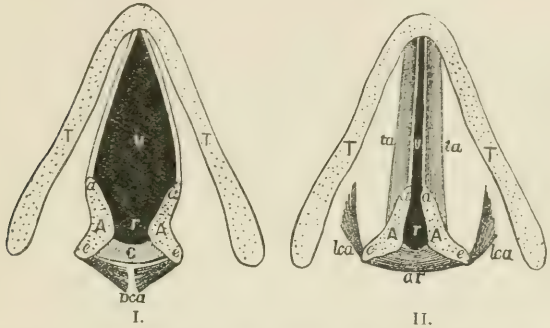


FIG. 120.—Transverse Section through the Larynx at the level of the vocal folds (true vocal cords). (TURNER'S *Anatomy*.)

I. The vocal folds are abducted and the rima glottidis is widely open.
II. The vocal folds are adducted. Notice the alteration in the position of the arytænoid cartilages.

A. Arytænoid cartilage.
C. Cricoid cartilage.
T. Thyreoid cartilage.
a. Vocal process of arytænoid cartilage.
at. Arytænoideus transversus.
c. Muscular process of arytænoid cartilage.
lca. Crico-arytænoideus lateralis.
pca. Crico-arytænoideus posterior.
r. Inter-cartilaginous part of rima glottidis (glottis respiratoria).
ta. Musculus vocalis.
v. Inter-membranous part of rima glottidis (glottis vocalis).

arytænoid joint, the vocal process is rotated in a medial direction (Fig. 120) when the muscle contracts. It is therefore an adductor of the vocal folds.

The **arytænoideus** muscle connects the two arytænoid cartilages, and its contraction draws them close to one another, posteriorly.

With the single exception of the crico-thyreoid, which is supplied by the external laryngeal nerve (p. 97), all the

muscles of the larynx are supplied by the **recurrent (laryngeal) nerve** (p. 99).

Laryngeal Paralysis.—Bilateral paralysis of the laryngeal muscles is practically always accompanied by paralysis of other muscles, *e.g.*, the soft palate, etc., innervated by the vagus. **Unilateral paralysis** may occur in neuritis of the vagus or it may be due to pressure on one of the recurrent nerves. In the latter case, the condition occurs more frequently on the left than on the right side, owing to the longer course which the left recurrent nerve adopts (p. 99). *Both nerves* may be affected in the neck by pleuritic thickening in apical phthisis, by enlargements of the thyreoid gland and by tuberculous adenitis of the antero-inferior group of the deep cervical lymph glands. In addition, the *right recurrent* may be compressed at the root of the neck by aneurismal dilatation of the innominate artery (p. 321). On the other hand, as it passes upwards within the thorax, the *left recurrent nerve* may be subjected to pressure from aortic aneurisms, mediastinal tumours and enlargement of the para-tracheal lymph glands.

When the recurrent (laryngeal) nerve is compressed, the fibres which innervate the abductor muscles are invariably the first to be affected. **Unilateral abductor paralysis** causes no alteration in the voice, and the condition can only be diagnosed by laryngoscopic examination, when it will be observed that the affected vocal fold does not become abducted during inspiration. Continuance of the pressure produces complete paralysis of the fold, which then assumes the cadaveric position. In this condition, the voice is rendered husky, since the breadth of the rima glottidis is greater than normal during phonation. The occurrence of pure **adductor paralysis** indicates that the disorder is functional in origin, and, as both folds are involved, the width of the rima glottidis is greatly increased. The condition, therefore, is characterised by complete aphonia.

In the early stages of **bilateral nuclear lesions**, bilateral abductor paralysis may occur. In this case, the voice is not

affected, but, owing to the narrowness of the rima glottidis, inspiration becomes laboured and difficult, and a slight degree of œdema glottidis may cause complete obstruction.

Bilateral paralysis of the crico-thyreoid results in relaxation of the vocal folds owing to the increased tonus of the unopposed vocalis and thyreo-arytænoid muscles. On laryngoscopic examination, the rima glottidis is observed to become slightly oval in outline when the vocal folds are adducted. The condition never occurs alone, and it is usually accompanied by other signs of vagus paralysis.

The Trachea and Bronchi

The **Trachea** begins at the lower border of the cricoid cartilage and extends downwards through the neck into the thorax. It terminates at the upper border of the fifth thoracic vertebra, which corresponds, in level, to the sternal angle (p. 294) on the anterior surface of the body and to the tip of the third thoracic spine on the posterior surface.

Except at its termination, which is often displaced slightly to the right, the trachea lies in the median plane, and it is separated from the vertebral column only by the œsophagus. This posterior bony relation is of importance, for it renders the trachea liable to become narrowed when compressed in an antero-posterior plane.

The isthmus of the thyreoid gland lies in front of the second, third and fourth rings of the trachea, and, when it becomes enlarged, it can exercise considerable backward pressure. Since the lobes of the gland are also involved, the trachea is gripped by the tumour and compressed against the vertebral column. This produces a mechanical obstruction to respiration, which is indicated by the characteristic "brassy" sound of the cough, and the condition is often aggravated by abductor paralysis of the vocal folds, due to pressure on the recurrent nerves (Fig. 50).

Within the thorax, the trachea is crossed by the arch of the

aorta (Fig. 113), and, therefore, may be subjected to pressure by aneurismal dilatations. It also lies behind the remains of the thymus gland, and may be compressed by tumours which have their origin in that structure.

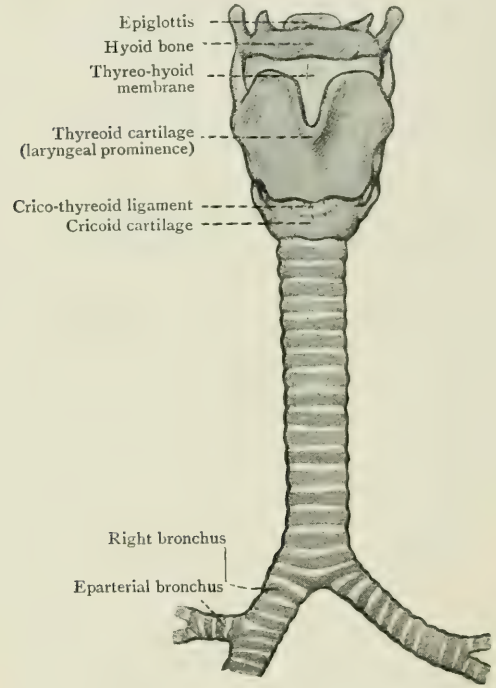


FIG. 121.—The Larynx, Trachea and Bronchi.

As the œsophagus is interposed between the trachea and the vertebral column, tumours which cause respiratory embarrassment by exercising pressure on the trachea may also give rise to difficulty in swallowing (Fig. 113).

The two **Bronchi**, nto which the trachea bifurcates, differ

from one another both in size and direction. The right bronchus is the wider but shorter of the two, and it is also stated to be more vertical in its course (Fig. 121). *Foreign bodies* which pass into the trachea almost invariably enter the right bronchus. This route is selected, partly because the right bronchus is the wider, and partly owing to the fact that the bifurcation is marked in the interior of the trachea by an antero-posterior ridge, which is placed slightly to the left of the middle line of the trachea (Fig. 113). As the foreign body descends, in most cases it impinges on the right side of this ridge—even when the bifurcation is placed to the right of the median plane—and so it is conducted into the right bronchus.

On this account, too, the orifice of the left bronchus may not be visible in *bronchoscopy*. It is, however, always possible to observe the vibrations of the left wall of the trachea, which are due to its intimate relationship to the aortic arch, and, if the point of the instrument is passed downwards in close contact with this wall, it will eventually enter the left bronchus.

One inch from its origin from the trachea, the right bronchus gives off the eparterial bronchus, which proceeds to the upper lobe of the right lung. The corresponding branch on the left side arises from the bronchus at a distance of 2 inches from the trachea. Owing to the proximity of the point of origin of the right apical bronchus to the trachea, bronchial breathing is frequently heard on auscultation of the right apex and does not necessarily possess any pathological significance.

The Pleural Cavities

Each lung is enveloped in a serous envelope, which is termed the **pleural sac**. The **pulmonary pleura** is firmly adherent to the surfaces of the lung and covers the contiguous surfaces of adjoining lobes. The **parietal pleura** lines the cavity in which the lung is situated; and, for descriptive purposes, is subdivided into—(1) The *costal pleura*, which lines the inner surfaces of the ribs and intercostal spaces;

(2) the *mediastinal pleura*, which covers the great vessels, etc.; (3) the *diaphragmatic pleura*, which covers the upper surface of the diaphragm; (4) the *cupula pleuræ*, which projects upwards into the neck in association with the apex of the lung. The pulmonary and parietal pleuræ become continuous with one another at the root of the lung (Fig. 123).

When a transverse section through the thorax above the level of the root of the lung is examined, it is found that there is no continuity between the parietal and the pulmonary pleuræ. The costal pleura lines the inner surfaces of the ribs

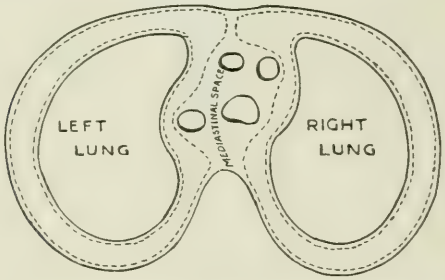


FIG. 122.—Diagram of a Transverse Section through the Thorax above the level of the root of the lung, showing the arrangement of the parietal and visceral layers of the pleura.

and passes medially on the posterior surface of the sternum to the median plane. It there becomes continuous with the mediastinal pleura, which passes backwards over the great vessels, etc., to reach the vertebral column. At the sides of the bodies of the vertebræ, the mediastinal pleura passes laterally on to the ribs (Fig. 122).

When a section through the thorax at the level of the root of the lung is examined, the arrangement is found to be very similar in regard to the costal pleura, but, as the mediastinal pleura passes backwards from the sternum, it comes into contact with the pericardium. From the pericardium the pleura is carried laterally on the anterior surface of the root of the

lung, and so establishes continuity with the pulmonary layer, which completely encircles the lung, finally returning to the posterior surface of the root (Fig. 123). It is then carried backwards to reach the vertebral column, where it becomes continuous with the costal layer.

The continuity of the costal and the diaphragmatic pleuræ can be demonstrated in frontal sections through the chest. From the cupula pleuræ, the costal layer descends on the ribs to a lower level than that occupied by the lower border of the lung during quiet respiration. It is then reflected on to the

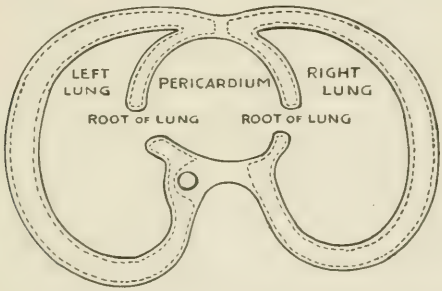


FIG. 123.—Diagram of a Transverse Section through the Thorax at the level of the root of the lung. The continuity of the visceral and the parietal layers is demonstrated in the figure.

upper surface of the diaphragm (p. 344), on which it passes medially till the pericardium is reached. In that situation the diaphragmatic layer becomes continuous with the pericardial portion of the mediastinal pleura, which ascends over the pericardium until it meets the lower border of the root of the lung, where it establishes continuity with the pulmonary pleura. At the upper border of the root of the lung, the pulmonary pleura again becomes continuous with the mediastinal pleura, which then ascends to the cupula pleuræ.

Surface Marking of the Pleural Sacs.—The apex of the lung extends upwards into the neck for ½ to 1 inch above the level of the clavicle. It is everywhere in contact with the

cupula pleuræ, so that the same line can be used to indicate both the apex of the lung and the pleural cupula on the surface of the body. This line commences at the junction of the medial and middle thirds of the clavicle, arches upwards and medially, and then descends to reach the sterno-clavicular joint. At its highest point, it lies not more than 1 inch above the clavicle.

The line along which the costal becomes continuous with the mediastinal pleura is known as the **costo-mediastinal line of reflection**. Its position differs slightly on the two sides of the body. On the right side, it begins at the sterno-clavicular articulation and passes downwards and medially to the middle of the manubrium. From this point it descends vertically till it reaches the level of the sixth chondro-sternal joint, which corresponds to the lower limit of the mediastinal pleura on the anterior surface of the body. On the left side, the upper part of the line is similar, but, opposite the fourth chondro-sternal articulation, it passes laterally to the margin of the sternum, along which it descends to the sixth costal cartilage (Pl. II.).

The lines of the two sides, therefore, overlap one another from the middle of the manubrium to the level of the fourth costal cartilage, but their upper and lower extremities are separated by small intervals. The V-shaped interval behind the upper part of the manubrium overlies the origins of the innominate and left common carotid arteries and the trachea, while in the lower interval the pericardium comes into direct apposition with the posterior surface of the sternum (p. 290). Light percussion over these areas gives a dull note, in consequence of these relations.

At the lower limit of the pleural sac, the costal pleura is reflected on to the upper surface of the diaphragm. The line along which this reflection takes place is not horizontal, but inclines downwards as it is traced laterally (Pl. II.). The **costo-diaphragmatic line of reflection** begins at the lower end of the costo-mediastinal line and passes down-

PLATE II. GENERAL VIEW OF THE ABDOMINAL AND THORACIC VISCERA.

The lines of pleural reflection are shown in blue.

PLATE III.—THE ABDOMINAL AND THORACIC VISCERA, FROM BEHIND.

The lower limit of the pleural sac is indicated by the blue line. Note the relation of the pleura to the spleen and to the twelfth rib.

wards and laterally behind the seventh costal cartilage and across the seventh intercostal space. In the *nipple line*, it crosses the bony extremity of the *eighth rib*. It continues to descend until it reaches the *mid-axillary line*, where it crosses the *tenth rib*. On the posterior surface of the body, the costo-diaphragmatic line of reflection ascends slightly as it passes medially. It crosses the eleventh and twelfth ribs and reaches the *vertebral column* opposite the lower border of the *twelfth thoracic vertebra* (Pl. III.). Thus the whole of the lower limit of the pleural sac is placed under cover of the ribs except its postero-medial corner, which descends below the neck of the twelfth rib. The same line may be used to map out the costo-diaphragmatic line of reflection on both sides of the body.

The **lower limit of the pleural sac** is placed at a much lower level than the lower border of the lung during quiet respiration, and throughout this area the costal and diaphragmatic pleuræ are in contact with one another. On the right side, the lower part of the pleural sac intervenes between the liver and the surface of the body, and, in consequence, it may be difficult to determine the presence of a small effusion in this situation. On the left side, this part of the pleura overlies the stomach anteriorly, and, when healthy, it does not cause any alteration in the tympanitic note obtained on percussion over that viscus. Effusions of fluid, however small, which gravitate downwards into this part of the left pleural sac, can readily be detected, since they encroach on *Traube's space* (p. 244) from above, and an area of dulness to percussion is found to intervene between the lung resonance above and the stomach tympanitis below. Posteriorly, on the left side, the pleural sac completely overlies the spleen, which may be thrust downwards from under cover of the ribs by large pleural effusions on the left side.

Pleuritic Effusions.—In health, there is a constant circulation of lymph through the pleural sac. The lymph enters the sac by a process of transudation from the neighbouring blood-

vessels and it leaves the sac through small *stomata*, which are found in both the pulmonary and parietal pleuræ, and which lead into small lymph vessels. Lymph, therefore, may pass from the pleural sac into the superficial lymph vessels of the lung and so reach the lymph glands at the hilus (p. 353), or it may enter the lymph vessels in the thoracic wall and so reach the internal mammary lymph glands. When the pleural membrane becomes inflamed, there is an increased flow of lymph into the sac, and at the same time the stomata may become obstructed by fibrinous threads. It has been suggested (West) that lymph only leaves the pleural sac during expiration, and, therefore, large effusions, which compress the lung so as to diminish its movement to a marked degree, remain unabsorbed. This view gains support from the fact that the removal of a part only of a large effusion is followed by re-absorption of the remainder, as it enables the excursions of the lung to be increased.

When the upper limit of a large pleural effusion is determined by percussion, it is very rarely found to be horizontal. Garland and others state that the upper border of the dull area forms a curve which is convex upwards, the summit of the curve being placed at some little distance from the posterior median line. Sahli, however, claims that, when light percussion is employed, it is possible to demonstrate that the upper border of the dull area is a horizontal line on the posterior aspect of the body but that it inclines downwards when traced forwards round the chest. He lays stress on the necessity for light percussion near the posterior median line, as it is only when that method is employed that the observer can avoid the alteration in the percussion note caused by the healthy lung of the opposite side. The same author suggests that the fluid spreads upwards more easily in the posterior part of the pleural sac as the posterior part of the lung, being more voluminous, possesses a greater retractive power than the anterior part.

Exploratory needling of the pleural sac is carried out

through an intercostal space and the needle is inserted across the upper border of the rib which bounds the space inferiorly in order to avoid the intercostal vessels and nerve, since they lie in relation to the lower border of the rib bounding the space superiorly.

The precise *site* of the puncture depends on the individual case, but care must be taken not to insert the needle too near to the upper or to the lower border of the dull area. In the former case, the lung is penetrated, and, in the latter case, the diaphragm may be pierced. When possible, the needle may be passed in through the fifth intercostal space in the mid-axillary line. In well-developed subjects it may be difficult to identify the fifth space in that situation, but it can be identified by drawing a line horizontally round the body at the level of the fourth chondro-sternal articulation. This line intersects the mid-axillary line on the fifth rib or fifth intercostal space.

The seventh space in the scapular line is a favourite site for puncture and also for the operation of **Paracentesis thoracis.** When the arm is by the side, the space is covered by the inferior angle of the scapula, but, when the arm is abducted or flexed beyond a right angle (p. 132), *e.g.*, by placing the hand on the top of the head, the space becomes uncovered. This site possesses the advantage that, when the instrument is withdrawn and the arm is replaced by the side, the track of the needle or cannula becomes obliterated to a large extent.

The NERVE-SUPPLY to the costal pleura is derived from the intercostal nerves; the diaphragmatic pleura receives branches from the phrenic nerve; the pulmonary pleura is supplied by the terminal branches of the pulmonary plexuses (p. 100). The pain of pleuritic inflammation may be referred to the peripheral sensory distribution of those nerves which have their centres in the spinal medulla at the same level as the nerves of supply to the pleura (p. 191). Abdominal pain and rigidity of the abdominal muscles are often associated with empyæma and with the pleurisy which accompanies the

onset of pneumonia. The skin areas and the muscles in question are supplied by the lower intercostal nerves, which are also stated to supply the costal pleura. It is, however, by no means certain whether the condition represents true viscero-sensory and viscero-motor reflexes, or whether the intercostal nerves are directly stimulated by the inflamed costal pleura, with which they are in contact for a short distance before they pass between the external and the internal intercostal muscles.

When the diaphragmatic pleura is inflamed, the terminal branches of the phrenic nerve are stimulated. The afferent impulses, therefore, pass to the fourth cervical segment of the spinal medulla, and they sometimes become conveyed to the cells which receive their impulses from the sensory branches of the fourth cervical nerve. When this occurs, pain is experienced in the area of distribution of the supra-clavicular nerves (Fig. 69).

The Lungs.—The Lungs occupy the pleural sacs. They contain a large amount of elastic tissue, which causes them to contract when the pleural sacs are opened. This elasticity is not sufficient to expel all the air from the alveoli, and therefore pieces of lung tissue float in water. In a fœtus which has not breathed the alveoli do not contain air, and portions of the lungs will sink when they are immersed in water.

The lungs are somewhat pyramidal in shape. The rounded apex extends upwards and completely fills the cupula pleuræ. The base is hollowed out to adapt itself to the shape of the diaphragm, on which it rests. The costal surface is separated from the mediastinal surface by a thin anterior and a rounded posterior border.

The **left lung** is divided into *two lobes*, an upper and a lower, by the *oblique fissure*, which cuts through the lung substance as far as the hilus, so that there is little or no structural continuity between the two lobes. On this account, disease cannot spread directly from one lobe to the other, unless their opposed surfaces

become adherent. The **right lung** is divided into *three lobes.* The lower lobe is very similar to the lower lobe of the left lung and is limited above by the oblique fissure, but a *transverse fissure* cuts off a middle lobe from the antero-inferior part of the upper lobe.

The **apex of the lung** can be mapped out on the surface of the body in the way described on page 344. It has already been shown that the costo-mediastinal lines of pleural reflection differ slightly on the two sides, and a similar difference, slightly exaggerated, exists between the anterior borders of the two lungs. The anterior border of the right lung corresponds exactly to the line of pleural reflection, but the anterior border of the left lung deviates widely from the line of pleural reflection below the level of the fourth chondro-sternal articulation (Pl. II.). As a result, there is a relatively large area of the pericardium which is only separated from the chest wall by the pleural sac. This area, together with the portion of the pericardium which is uncovered by pleura (p. 290), is therefore dull to percussion and constitutes the area of superficial cardiac dulness (p. 296). A small, tongue-like process of lung tissue projects medially in the fifth intercostal space from the notch in the anterior border of the left lung (Fig. 106). It sometimes becomes consolidated in phthisis or pneumonia of the upper lobe, and it then gives rise to an increased area of cardiac pulsation.

In quiet respiration, a definite interval exists between the lower border of the lung and the lower limit of the pleural sac. This interval increases in extent as it is traced laterally, and so, whereas it only amounts to $1\frac{1}{2}$ inches in the nipple line, it may be as much as $3\frac{1}{2}$ or even 4 inches in the mid-axillary line. On the posterior surface of the body, the interval again decreases, and, in the scapular line, it is about $1\frac{1}{2}$ inches in depth. In forced inspiration, the lower borders of the lungs descend almost to the lower limit of the pleural sac, and areas which were dull or tympanitic to percussion during quiet breathing become resonant.

Surface Marking of Lung Fissures.—The *oblique fissure* of the lung corresponds to a line drawn from the second thoracic spine downwards and laterally through the root of the spine of the scapula and across the infra-spinous fossa. It is continued downwards and forwards round the side of the body, and cuts the inferior border of the lung on the sixth costal cartilage. The *transverse fissure* may be indicated by a line drawn horizontally to the right from the middle of the sternum at the level of the fourth costal cartilage until it meets the oblique fissure in the mid-axillary line.

When the fissures are mapped in on the surface, it is found that the upper lobe is most accessible from the anterior aspect of the body, and the lower lobe from the lateral and posterior aspects. The middle lobe of the right lung can only be satisfactorily examined from the front of the chest, as it tails off rapidly into the axilla.

The relations of the fissures of the lung to the surface of the chest are of importance in the diagnosis of interlobar empyema. In this condition the area of dulness occurs on the line of one of the fissures.

The **Apex of the Lung** projects upwards into the root of the neck for from a half to one inch above the clavicle, but this upward projection is entirely due to the obliquity of the first rib, which slopes downwards from the vertebral column to the manubrium sterni. *Anteriorly*, above the clavicle, the apex is related to the sterno-mastoid and the scalenus anterior muscles, and it is crossed by the first part of the subclavian artery. *Medially*, it is related to the trachea, from which it is separated by the carotid sheath and its contents. This relationship is of importance because, owing to the slope of the neck, the apex of the lung is usually percussed in a backward and medial direction, and so the lung note is altered by the tracheal resonance. To avoid this complication, direct backward percussion may be employed or the tracheal resonance may be more easily eliminated if the patient is instructed to keep the mouth open during the examination.

Posteriorly, the apex rests on the neck of the first rib and the vertebral end of the first intercostal space. Two nerves intervene between the rib and the pleura. They are the sympathetic trunk and the anterior ramus of the first thoracic nerve, which is passing upwards and laterally to take part in the formation of the brachial plexus. Either of these structures may be involved in the pleuritic thickening which accompanies phthisis and apical pneumonia. When the sympathetic is affected, certain vaso-motor symptoms may arise, such as unilateral sweating or localised areas of flushing. Sometimes the fibres which ultimately supply the dilatator pupillæ muscle are picked out, and the pupil on the affected side is markedly dilated. Pressure on the sympathetic trunk may account for the severe cerebral symptoms which occasionally complicate cases of apical pneumonia. Involvement of the first thoracic nerve is indicated by the presence of painful or hyperæsthetic areas on the medial side of the arm.

Lombardi's "varicose zone of alarm," which is believed to constitute an important aid to the early diagnosis of apical phthisis, depends on the close relation of the intercostal veins to the costal pleura. As they lie on the posterior thoracic wall, the intercostal veins are in direct contact with the costal pleura. The *first intercostal vein* arches forwards over the cupula pleuræ (p. 342) to join the innominate vein. The veins which drain the second and third intercostal spaces unite to form the *superior intercostal vein*. On the right side, this vessel joins the *vena azygos (major)*, which pours its blood into the superior vena cava; on the left side, it crosses the arch of the aorta obliquely and terminates in the left innominate vein. All the intercostal vessels receive tributaries from the tissues of the back as well as from the intercostal muscles, etc.

The pleural thickening which is commonly associated with apical phthisis may be sufficient to compress the veins which drain the upper spaces, and, as a result, venous varicosities occur on the dorsal aspect of the body near the seventh cervical and the upper three thoracic spines. Owing to the

greater frequency of tuberculous disease in the right apex, the sign is more frequently present on the right side.

Lombardi claims that this "varicose zone of alarm" is present in nearly 90 per cent. of cases of primary tuberculosis of the apex.

The antero-inferior group of the **deep cervical lymph glands** lie in relation to the medial border of the scalenus anterior, and some members of the group are in contact with the cupula pleuræ. These glands receive their afferents from the tonsillar lymph gland, amongst others, and they are, on that account, frequently the site of tuberculous infection. In order to account for the frequency of apical phthisis, the theory has been put forward that the lung apex is infected from the deep cervical lymph glands through the pleura, which first becomes thickened and adherent.

The relationship which the **clavicle** bears to the apex of the lung is important, because it indicates that percussion over the clavicle is of little value unless precisely similar points are chosen on the two sides, when comparisons are being made. The medial inch and a half of the clavicle lies directly in front of the apex, from which it is separated only by the sterno-hyoid muscle and the innominate vein. Percussion over this part of the bone gives a resonant note, but its character is affected by the damping influence of the "plectrum." Immediately lateral to this portion, the clavicle is separated from the lung by the first rib, and the percussion note consequently alters in character. Beyond the first rib, the clavicle forms the anterior boundary of the apex of the axilla, but a resonant note is obtained on percussion, as the "plectrum" is no longer placed on the sternal extremity, which is therefore able to vibrate freely.

The **Base of the Right Lung** is deeply hollowed out to accommodate itself to the right cupola of the diaphragm, which is thrust upwards by the large right lobe of the liver. The margins of the base form the thin lower border of the lung, and, in order to determine the precise downward extent of the right lung, very light percussion must be used.

Tropical abscess of the liver causes adhesions to form between the liver and the diaphragm, and it may burst through the diaphragm into the right pleural sac, giving rise to an empyæma. If the diaphragmatic pleura is adherent to the base of the lung, the abscess may rupture into the lung and be discharged by coughing. It should be remembered that the cough reflex is not brought about until the pus comes into contact with the trachea or, perhaps, with one of the larger bronchi. As a result, in these cases and in bronchiectasis and large phthisical cavities, once the cough reflex is started, it is continued until all the movable pus is evacuated. The patient then enjoys a quiescent period until a fresh accumulation reaches the larger air-passages and so induces another outbreak.

The **Base of the Left Lung** overlies the left lobe of the liver, the stomach and the upper half of the spleen (p. 404).

The *mediastinal surface of the right lung* is in relation, below and in front of the hilum, to the pericardium covering the right atrium. Above the hilum, it is in direct contact with the trachea, and this relationship helps to explain why bronchial breathing may be heard on ausculting a perfectly healthy right apex (p. 341). Above the hilum of the left lung, the trachea is separated from the mediastinal surface by the left subclavian artery, but the œsophagus, which projects slightly to the left side of the median plane, and the thoracic duct are often in direct apposition. On this account, œsophageal sounds may be audible at the left apex.

The **Lymph Vessels** of the lung join the broncho-pulmonary lymph glands, which are situated in the neighbourhood of the hilum. Some of the efferents from these glands pass directly to the thoracic duct, but others join the glands around the bifurcation of the trachea. From the latter group, efferents pass upwards to the para-tracheal glands, which communicate freely with the inferior group of the deep cervical glands. This indirect connexion between the lymph vessels of the lung and the cervical glands may offer a channel for the

passage of infection when the latter group is the site of tuberculous disease (p. 352).

The Movements of Respiration.—In the healthy adult male, the increase in the capacity of the thorax which is necessary during inspiration is obtained by the descent of the diaphragm, and, to a much lesser degree, by the contraction of the intercostal muscles. With each *inspiration* the fleshy fibres of the diaphragm, which are slightly arched, straighten out and pull on the central tendon. As a result of the straightening out of the fleshy fibres, the abdominal viscera are pressed downwards and the relaxed muscles of the abdominal wall are bulged in an outward direction. The central tendon descends, but only to a very slight extent, the amount of which may be gauged by placing the finger on the thyreoid prominence during deep respiration. The movement is transmitted from the central tendon to the fibrous pericardium, and from the fibrous pericardium to the pretracheal fascia. *Expiration* is brought about by the recoil of the muscular abdominal wall, which presses the abdominal viscera upwards against the diaphragm, causing it to resume its rounded dome-like shape. This variety is known as the **abdominal** or **abdomino-thoracic type** of respiration.

In the adult female, the type of respiration is termed **thoracic** or **thoracico-abdominal**. The effect of the diaphragm is much less marked, and, to make up for this diminution in vertical depth, the transverse and antero-posterior diameters of the thorax are definitely increased during inspiration. This result is obtained by the action of the intercostal muscles, which raise the ribs "like pail handles." This movement increases the transverse diameter of the thorax and it also increases the antero-posterior diameter, as the sternal extremities of the ribs are thrust forwards and they carry the sternum with them. The elevation of the eighth, ninth and tenth ribs, which are not attached directly to the sternum, causes an increase in the infra-costal angle, so that not only is the transverse diameter of the thorax increased, but, as more

room is provided for the abdominal viscera, the strain is taken off the muscular abdominal wall. As a result, although the actions of the diaphragm are not suspended, they are not indicated by the outward bulging of the abdominal wall, which is no longer necessary. Expiration is caused by the elastic recoil of the ligaments of the costo-vertebral and the chondro-sternal joints. The accompanying diminution of the infra-costal angle acts through the abdominal viscera to restore the diaphragm to its position of rest.

The Cheyne-Stokes type of respiration is exhibited in the late stages of arterio-sclerosis, uræmia and other conditions. Pauses, during which respiration is completely inhibited, alternate with phases in which the respiratory excursions gradually increase to a maximum and then gradually diminish. Traube has suggested that, owing to the disease, the excitability of the respiratory centre is decreased. During the pause the blood becomes increasingly venous in character and eventually the centre responds to a stimulus which is abnormally strong. The oxidation of the blood by the respiratory phase weakens the stimulus so that it again becomes insufficient to bring about a response.

The phenomenon known as *hiccough* is due to a spasmodic contraction of the diaphragm, accompanied by a spasmodic closure of the glottis. It is usually a reflex result of stimulation of the stomach, heart, peritoneum, etc.

Paralysis of the Diaphragm.—When the diaphragm is paralysed, the intercostal muscles are required to produce a still greater increase in the transverse and antero-posterior diameters of the thorax, and in this they are aided by all the extraordinary muscles of respiration. The consequent increase in the capacity of the abdomen, which is due to the widening of the infra-costal angle, causes the anterior abdominal wall to *collapse* in the epigastric region with each inspiration.

Respiration in Emphysema.—In emphysema the capacity of the thorax in the position of rest is increased to its maximum, so that the intercostal muscles are thrown out of action. The

extra capacity required in inspiration is obtained by the diaphragm, which is aided by the accessory muscles. The part played by the latter group is well shown when an emphysematous patient has a fit of coughing. The upper limbs and their girdles are fixed so that those muscles which pass between them and the chest wall may act on the latter. In this way, the pectoral muscles elevate the ribs and the sternum, the serratus anterior elevates the ribs, and its digitations of origin stand out in relief on the medial wall of the axilla. The latissimus dorsi elevates the lower ribs and draws them outwards so as to increase the capacity of the abdomen and lessen the resistance against which the diaphragm has to act. In addition to the fixation of the upper limbs, the head is kept fixed in the middle line to enable the sterno-mastoids to act on the manubrium sterni, and the scalene muscles to act on the upper two ribs.

Nerve-supply of the Lungs.—The lungs receive their nerve-supply from the anterior and posterior pulmonary plexuses, which lie in relation to the root. The vagus and the sympathetic trunk share in the formation of both plexuses, and their branches accompany the vessels and bronchi into the lungs. It seems probable that the circular muscular coat of the smaller bronchi is innervated through the vagus. In *spasmodic asthma*, the circular muscle fibres become tonically contracted, producing profound respiratory embarrassment. The condition may be initiated reflexly by the stimulation of the gastric branches of the vagus nerves.

It is a matter of common experience that large areas of lung tissue may be destroyed by disease and yet the process is perfectly painless. Unfortunately, no satisfactory anatomical explanation can be offered, for it is not sufficient to state that lung tissue is insensitive to pain stimuli, as it might reasonably be expected that the pain would be referred to the cutaneous distribution of the intercostal nerves, since the sympathetic fibres which supply the lung have their centres in the thoracic region of the spinal medulla.

VI

THE GENITO-URINARY SYSTEM

The Kidneys

The **Kidneys** are situated, for the most part, in the epigastric and hypochondriac regions (p. 234), but their lower poles extend for a short distance below the subcostal plane. On account of the great bulk of the right lobe of the liver, the right kidney lies at a somewhat lower level than the left kidney, but this difference in position is subject to considerable variation.

As a general rule, the transpyloric plane passes through the hilum of the right kidney a little above its middle, whereas it cuts the hilum of the left kidney a little below its middle.

The long axes of the kidneys are placed obliquely, so that the upper pole of the organ, which is almost entirely under cover of the costal margin, is nearer to the median plane than the lower pole, which projects downwards beyond the level of the costal margin (Fig. 124). In length the kidney measures about $4\frac{1}{2}$ inches, and it is about $2\frac{1}{2}$ inches wide. The hilum lies $1\frac{1}{2}$ to 2 inches from the median plane.

When the position of the transpyloric plane has been determined, the information given above is sufficient to enable the outline of the kidney to be mapped out on the surface of the body.

Relations. 1. **Anteriorly.**—Both kidneys are retro-peritoneal and, therefore, their normal range of movement is exceed-

ingly small. *On the right side*, the greater part of the anterior surface is related to the inferior aspect of the right lobe of the liver, but, near its lower pole, it is covered by the right (hepatic) flexure of the colon (Fig. 97). Enlargements of the right kidney may extend downwards behind the flexure and the ascending colon, or they may thrust the colon downwards. In the latter case, the dulness of the tumour to percussion is continuous with the hepatic dulness, and it may be a matter

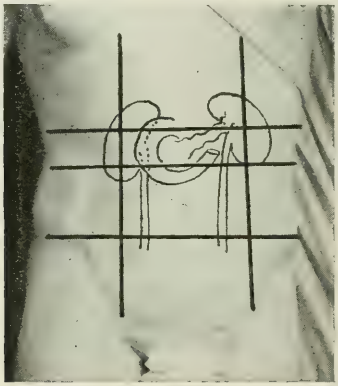


FIG. 124.—Anterior Aspect of the Trunk, showing the surface relations of the kidneys and ureters, the duodenum and the pancreas.

NOTE.—The reference lines are the same as those shown in Fig. 87.

of some difficulty to determine whether the tumour has arisen in connexion with the kidney or with the liver. In other cases, the colon becomes stretched across the anterior aspect of the tumour, so that, on percussion, a tympanitic zone is found crossing the dull area.

On the left side, the kidney is crossed anteriorly by the body of the pancreas, which occupies a broad strip a little above the middle of the viscus (Fig. 125). Above the pancreas, the left kidney is related to the spleen and the supra-renal gland, and it helps in the formation of the stomach-bed (p. 245). Below

the pancreas, the lateral border of the left kidney is in contact with the left (splenic) flexure and with the descending colon; a fairly large area near the lower pole is related to the first coils of the jejunum.

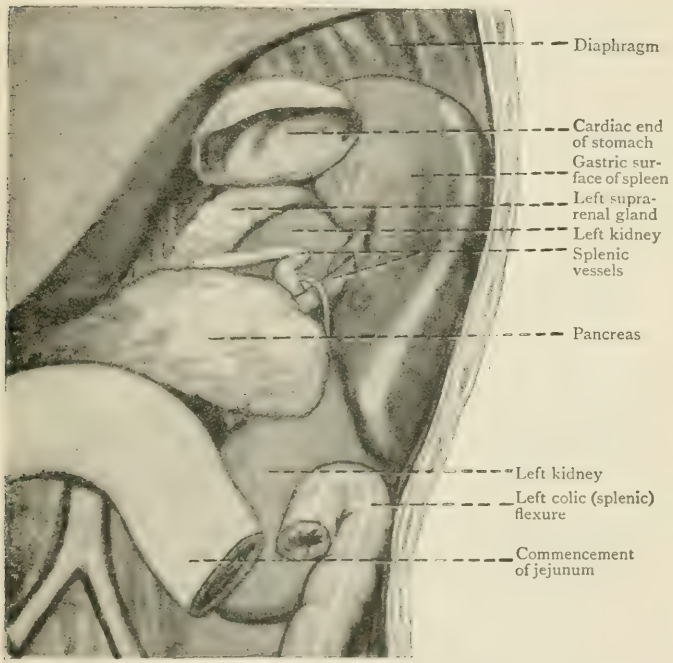


FIG. 125.—The relations of the Left Kidney and the Viscera which form the "bed" of the Stomach.

As the left kidney is covered not only by its intimate relations, but also by the stomach and the greater omentum, small tumours cannot be detected by palpation.

2. **Posteriorly.**—The posterior relations of the two kidneys are very similar. The upper third, or more, of the kidney rests on the posterior fibres of the diaphragm. The lower

half or two-thirds is in contact with three muscles; from the medial to the lateral side these are the psoas major, the quadratus lumborum, and the transversus (Fig. 97). Between the kidney and the latter two muscles, the subcostal nerve (T. 12) and the ilio-hypogastric and ilio-inguinal nerves (L. 1) pass obliquely downwards and laterally, round the abdominal wall. Tumours of the kidney may compress these nerves and give rise to painful symptoms which are referred to the areas of their peripheral distribution, *i.e.* the lower part of the abdominal wall and the proximal parts of the thigh and the buttock (Fig. 74).

Movable Kidney.—This condition must be distinguished from **Floating Kidney,** which is an extremely rare anomaly. In the latter case, the kidney is invaginated into the peritoneal cavity, and is attached to the posterior abdominal wall by peritoneal ligaments, whereas, in movable kidney, the viscus retains its normal relationship to the peritoneum, *i.e.* it remains entirely retro-peritoneal.

The two kidneys are enclosed in a large fascial *capsule*, which also contains the aorta, the inferior vena cava, the renal vessels and the commencements of the two ureters (Gerota's Space). It is said that the capsule may extend downwards beyond the lower pole of the kidney, and that this condition constitutes an important predisposing cause of movable kidney.

The symptoms produced by this condition are usually very vague and difficult to define, and it is probable that they are caused, for the most part, by the weight of the viscus dragging on the peritoneum, on the renal vessels, and on the sympathetic nerves, which lie on their coats.

Palpation of the Kidney.—In highly neurotic individuals, the abdominal walls may be so lax that palpation of the anterior surfaces of the kidneys can be carried out with surprising ease. In such cases, the vertebral column and the abdominal aorta can also be felt without any difficulty.

In order to palpate the kidney, one hand should be placed on the dorsal aspect of the trunk below the twelfth rib so as

to thrust the viscus forwards, while the other hand is placed on the anterior abdominal wall, just below the costal margin. The patient is instructed to take a deep breath, and, as the abdominal wall collapses with expiration, the anterior hand is pressed backwards and upwards under the costal margin in an endeavour to catch the lower pole of the kidney between the two hands.

If the examination is carried out with the patient in the dorsal decubitus, it may not be easy to determine whether the kidney is movable or not. On this account the examination should be repeated with the patient sitting up, or, if possible, in the erect attitude.

NERVE-SUPPLY.—The kidney receives its nerve-supply from the renal plexus, which is an off-set from the aortic plexus of sympathetic nerves (p. 188). These nerves have their centres in the lower thoracic segments of the spinal medulla.

As in the case of the liver (p. 264) and the lung (p. 356), pathological processes may cause serious and even fatal lesions of the kidney, without giving rise to any painful symptoms referable to the viscus.

Tumours of the Kidney, however, may give rise to referred pain, not by a "viscero-sensory reflex" (p. 192), but by direct pressure on the subcostal, ilio-hypogastric and ilio-inguinal nerves (p. 360). Further, painful symptoms may be present in cases of movable kidney owing to traction on the sympathetic nerves or on the peritoneum.

As a result of the absence of painful symptoms, for the diagnosis of renal conditions the physician is almost entirely dependent on the examination of the urine and the blood-pressure, and, in some cases, he may receive additional information from radiograms.

The **Ureter.**—The ureter begins at the hilum of the kidney and descends vertically through the abdomen at a distance of about $1\frac{1}{2}$ inches from the median plane. When perfectly normal, the ureter lies directly in front of the tips of the transverse processes of the lumbar vertebræ, from which it is

separated by the psoas major muscle, and it crosses the bifurcation of the common iliac artery at the upper aperture (brim) of the pelvis. It then passes downwards in front of the sacro-iliac joint and curves forwards and medially to enter the supero-lateral angle of the basal, or posterior, surface of

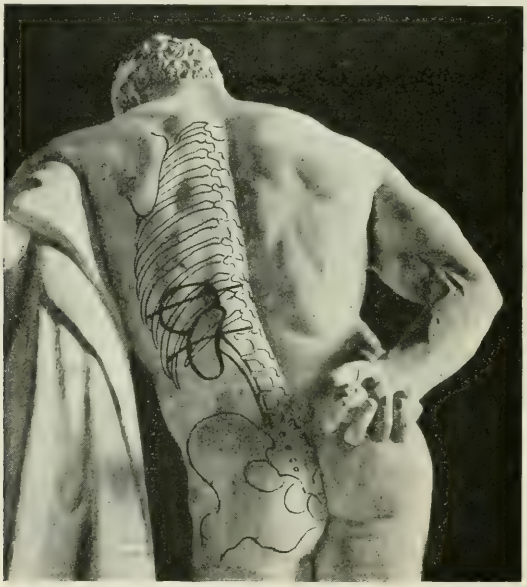


FIG. 126.—The Spleen and the Left Kidney and Ureter outlined on the Dorsal Aspect of the Body. The lower border of the left lung and the lower limit of the left pleural sac are also shown.

the bladder. The termination of the ureter in the adult lies on a level with the second or third piece of the coccyx.

As it descends through the abdomen, the ureter is crossed by the mesentery and the terminal part of the ileum, on the right side, and by the pelvic meso-colon, on the left side.

Four slight *constrictions*, which are sufficient to delay the passage of a calculus, occur in the normal ureter. They are

placed—(1) At its commencement; (2) opposite the transverse process of the third lumbar vertebra; (3) at the upper aperture (brim) of the pelvis; and (4) at its termination. The positions of these constrictions and the relation of the ureter to the transverse processes must be borne in mind in the examination of radiograms, as, in this way, shadows thrown by impacted calculi may be differentiated from shadows thrown by calcareous lymph glands, etc.

The ureter receives its *blood-supply* from the arteries to which it is related as it descends from the kidney to the bladder. They include the renal, spermatic, common iliac and superior vesical arteries. The vessels conduct to the ureter *nerves of supply* from the sympathetic nervous system, and these nerves have their origin in the lower thoracic and the upper lumbar regions of the spinal medulla.

The ureter possesses a complete coat of unstriped muscle, and it is believed that the passage of urine from the kidney to the bladder is brought about by waves of peristalsis. The presence of pus, a calculus or other foreign material in the ureter produces excessive peristaltic contractions, which are always associated with more or less acute pain.

Ureteral Colic.—The **Pain** in ureteral colic has a characteristic distribution, which is of great help in diagnosis. When the wave of contraction passes along the whole length of the ureter, the pain commences on the dorso-lateral or dorsal aspect of the trunk in the lumbar region. As the peristaltic wave passes down, the pain passes round the trunk, but it descends so as to reach a lower level in front than behind, and it may finally radiate into the testis.

Since the thoracic nerves supply strips of skin which are almost horizontal (Fig. 69), it follows that the pain is not confined to the distribution of a single nerve, but that it spreads from the area supplied by one nerve to that supplied by the nerve below. From examination of Figs. 60 and 61 it will be seen that the pain in ureteral colic is experienced in the regions supplied by the tenth, eleventh and twelfth thoracic and the

first lumbar nerves. The pain may also be felt in the proximal part of the thigh (lumbo-inguinal nerve, p. 165) and in the buttock (iliac branches of T. 12 and ilio-hypogastric, etc.). Further, the pain never affects the skin of the scrotum (S. 2, 3 and 4, p. 184), except in its proximal part (ilio-inguinal nerve, L. 1, p. 163).

The **testicular pain** is explained (Mackenzie) by the fact that the external spermatic nerve (genital branch of genito-crural, L. 1 and 2) supplies a few sensory twigs to the tunica vaginalis testis.

The character, distribution and method of spread of the pain in ureteral colic combine to support the view that the pain is not experienced in the ureter itself. Ureteral colic, therefore, may be regarded as an excellent example of the "viscero-sensory reflex."

At the same time it is very interesting to observe that cases of ureteral colic often show a well-marked "viscero-motor reflex" (p. 197). During the attack, the patient feels that the testis is drawn up towards the abdomen and local examination may reveal some boarding of the lower fibres of the internal oblique and the transversus muscles. The upward movement of the testis is produced by the *cremaster muscle*, which covers the testis and the spermatic cord. This muscle is really a part of the internal oblique, and it receives its nerve-supply from the external spermatic nerve (genital branch of genito-crural) (L. 2). The lower parts of the internal oblique and the transversus muscles are supplied by T. 10, 11 and 12, and L. 1. It is evident that the "overflow" (p. 191) of abnormal afferent impulses from the ureter may stimulate the cells which are concerned in the innervation of the internal oblique, transversus and cremaster muscles.

Attacks of ureteral colic, however, do not always begin in the area of distribution of the tenth thoracic nerve. They may commence either one or two segments lower down. If the history of a case shows that attacks of pain, which originally began at a higher level, have more recently begun at a lower

level in the abdominal wall, the inference that the pain is due to an ureteral calculus, and that the calculus has travelled some distance down the ureter would appear to be quite justifiable.

It is also important to remember that attacks of ureteral colic do not necessarily imply either complete obstruction or even impaction in the tube. A small calculus in the pelvis of the ureter may be quite sufficient to produce severe attacks of colic, while it may be impossible to detect its presence by means of radiograms.

It has been said that the pain in renal calculus may be referred entirely to the opposite side of the body, but this statement has not been confirmed. From the fact that the ureter does not develop in the median plane originally, such an occurrence would be very difficult to understand.

Areas of cutaneous or muscular hyperalgesia (p. 195) may develop in connexion with renal calculi, and they are not infrequently found in the areas supplied by the posterior rami (primary divisions) of T. 10, 11 and 12, and L. 1 (Fig. 60).

The Bladder.—*In the newly-born infant*, the bladder projects upwards from the pelvis into the abdominal cavity, and its anterior surface is in direct contact with the anterior abdominal wall. As the relative size of the pelvic cavity increases, it sinks downwards, and, *in the adult*, it is only when it is distended that the bladder rises up out of the pelvis.

When it is empty, the bladder is roughly pyramidal in shape. The **apex** lies in contact with the pelvic surface of the pubic symphysis, and the **base** is directed downwards and backwards towards the rectum. The **superior surface** of the bladder looks upwards and backwards, and is in relation to coils of the small intestine or pelvic colon, while the **infero-lateral surfaces** look downwards and laterally, and are related to the pubes and to the floor and side walls of the pelvis. The *retro-pubic space* (*of Retzius*), which contains a small pad of fat, intervenes between the bladder and the pubic symphysis. The **neck** of the bladder, which is partly continuous with the prostate, is traversed by the internal orifice of the urethra.

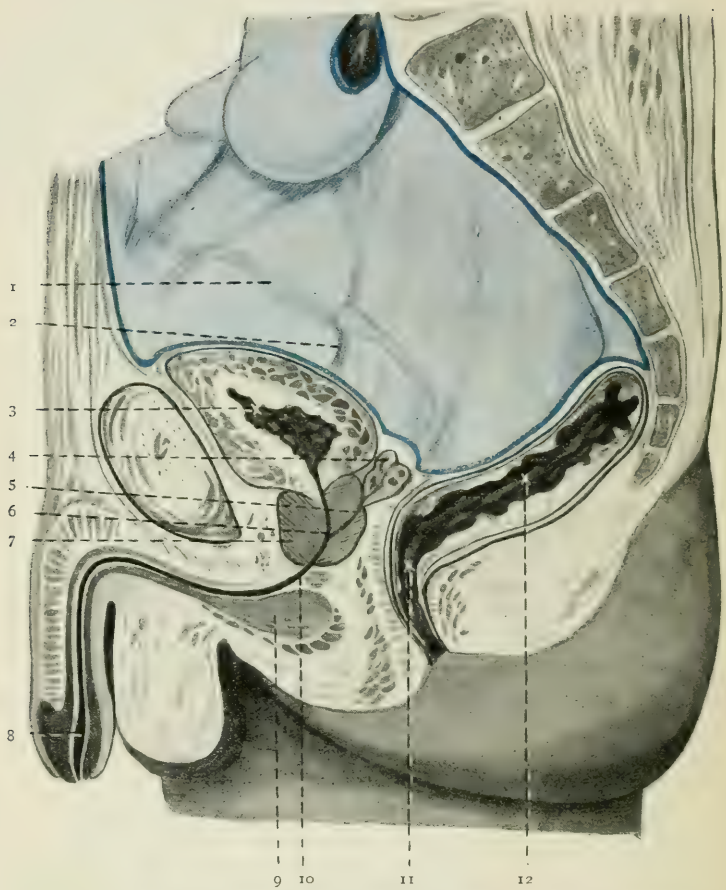


FIG. 127.—Median Sagittal Section of Male Pelvis, showing the relations of the viscera and the arrangement of the peritoneum, which is indicated in blue. The cut edges of the peritoneum are represented by the dark blue lines.

1. Ductus (vas) deferens.
2. Ureter.
3. Bladder.
4. Seminal vesicle.
5. Ejaculatory duct.
6. Prostatic urethra.
7. Prostate.
8. Fossa navicularis.
9. Bulb.
10. Urethra.
11. Anal canal.
12. Rectum.

The **peritoneum** covers the whole of the superior surface of the bladder, but it does not clothe the posterior (Fig. 127) or the infero-lateral surfaces. Anteriorly, it is reflected from the apex of the bladder on to the anterior abdominal wall, and laterally it passes from the upper surface on to the side walls of the pelvis. Posteriorly, the peritoneum touches the fundus of the seminal vesicle (Fig. 127) and passes backwards to the anterior surface of the rectum.

When the bladder fills, it rises up out of the pelvis into the abdomen, since it is unable to thrust the prostate downwards owing to the presence of the urogenital diaphragm (p. 379), which fills up the pubic arch. As the viscus distends, the superior and the infero-lateral surfaces become increased in size, but the posterior surface is not much altered. The peritoneum which covers the superior surface of the empty bladder cannot stretch sufficiently to enable it to cover the whole surface when the viscus is enlarged. As a result, the bladder strips the peritoneum off the anterior abdominal wall and the side walls of the pelvis. In this way, the anterior part of the inferior aspect of the bladder is brought into contact with the lower part of the transversalis fascia, and no peritoneum intervenes between the two structures (Fig. 128). In cases, therefore, in which the surgeon is unable to draw off the urine from a distended bladder *per urethram*, the bladder may be punctured supra-pubically without fear of infecting the peritoneal cavity. In some cases, however, leakage occurs into the retropubic space (of Retzius).

The **mucous membrane** of the bladder is redundant and is thrown into folds when the viscus is empty. The underlying submucous tissue is very loosely arranged and, therefore, the muscular and mucous coats are not firmly adherent to one another. On account of this arrangement, it is possible for the bladder to become distended without any undue stretching of the mucous membrane.

It has already been pointed out that the posterior surface of the bladder undergoes but little alteration, while the

superior and infero-lateral surfaces are becoming increased in size. It is in conformity with this fact to find that the mucous coat on the internal aspect of the posterior surface is smooth and unfolded, even when the bladder is empty. This area, sometimes termed the **internal trigone**, differs from the rest of

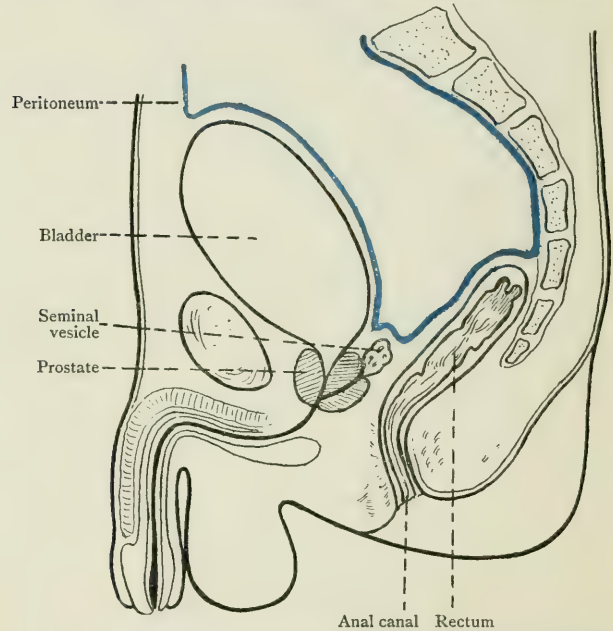


FIG. 128.—Median Sagittal Section through Male Pelvis, showing the disposition of the peritoneum when the bladder is distended.

the bladder not only in the arrangement of its mucous coat, but also in its nerve-supply (*vide infra*).

It is frequently important to determine whether epithelial cells in urinary deposits are derived from the renal tubules or from the urinary passages. Renal epithelial cells are usually cubical or spherical in shape, whereas the cells from the bladder are flat, and they may be round or polygonal in out-

line. But, if the cells of the deeper strata are thrown off, it becomes more difficult to determine their origin since they are provided with tail-like processes in both the kidney and the bladder. A marked predominance of these cells in the deposit is more suggestive of pyelitis than of cystitis (Sahli).

The large cells of the pavement epithelium of the vagina or prepuce are frequently found in the urine.

Development of the Bladder.—The whole of the urinary bladder is derived from the ventral portion of the **cloaca**.

At the end of the third week of fœtal life, the alimentary canal consists of a short tube, closed at both ends but communicating freely with the **yolk sac** on its ventral surface (Fig. 1). A little caudal to this communication a short blind diverticulum extends from the ventral aspect of the gut into the body-stalk. This diverticulum is termed the **allantois**, and it plays an important part in the development of the bladder in some mammals. In man, however, it is very small, and, as will be described, it takes no part in the formation of the bladder.

On the cephalad aspect of the angle between the allantois and the hind-gut, a transverse mesodermal septum grows tailwards and subdivides the cloaca into a ventral, urinary, and a dorsal, gut, segment (Fig. 129). The **Wolffian ducts** (p. 380) establish connexions with the lateral aspects of the cloaca, and when the latter becomes subdivided, they maintain their connexion with its ventral portion. Before the subdivision of the cloaca is completely effected, the ureter arises as an out-growth from the caudal extremity of the Wolffian duct and grows headwards. Later, owing to a difference in the relative rates of growth, the ureters come to open into the urinary segment of the cloaca independently of the Wolffian ducts.

It will been seen, therefore, that the bladder arises from the ventral portion of the hind-gut, and that it is cut off from a portion of the gut-tract, which, although very small originally, is destined to form the whole of the large intestine. It is not surprising, therefore, to find that the nerve-supply of the

bladder and the nerve-supply of the large intestine are practically identical (p. 284).

While the partition of the cloaca is being carried out, the ventral wall loses its mesoderm in a part of its extent, and this area, in which the endoderm of the gut comes into apposition with the ectoderm of the body-wall, is termed the **cloacal membrane**. The tailward-growing septum meets the cloacal membrane and separates it into a ventral, genito-urinary part and a dorsal, anal part, which closes in the gut segment.

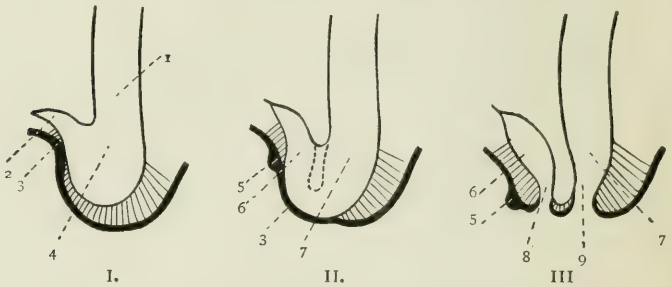


FIG. 129.—The Development of the Bladder.

In I., the cloacal membrane is just beginning to form. In II., it is very extensive, and the cloaca is being divided into ventral and dorsal portions. In III., the sub-division of the cloaca is complete and the uro-genital and anal membranes have ruptured.

1. Hind-gut.
2. Allantois.
3. Cloacal membrane.
4. Cloaca.
5. Genital tubercle.
6. Ventral, urinary, part of cloaca.
7. Dorsal, gut, part of cloaca.
8. Perineal orifice of uro-genital sinus.
9. Anal orifice.

Under normal conditions these membranes break down during the third month of fœtal life. The **anal membrane** has already been considered (p. 287). The **genito-urinary membrane** breaks down caudal to the **genital tubercle**, which consists of a heaping up of the surface ectoderm at the cephalic extremity of the membrane (Fig. 129). This perineal orifice persists in the female, but it undergoes certain changes in the male.

Two elevations, termed the **labio-scrotal folds**, form one on each side of the genital tubercle and grow tailwards. In the

female they remain separated by the pudendal cleft and form the labia majora. In the male, they fuse with one another, caudal to the genital tubercle, and they thus roof in the perineal orifice of the bladder, which then opens on the caudal surface of the tubercle. The genital tubercle forms the penis and the urethral orifice is situated at the base of the glans, which becomes canaliculised at a slightly later period. The urethra thus acquires its normal external orifice, and the opening at the base of the glans disappears.

Congenital Anomalies of the bladder and urethra are by no means uncommon. In the condition of **epispadias** the urethra opens on the dorsal aspect of the penis, which is more or less malformed. A similar deformity may occur in the female, the urethra opening on the dorsal aspect of the clitoris. This condition is brought about by rupture of the genito-urinary membrane on the cephalic instead of on the caudal aspect of the genital tubercle.

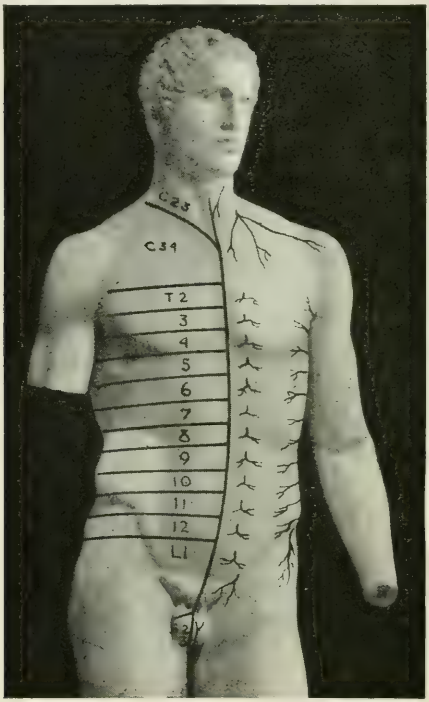
Hypospadias, which is the normal condition in the female, may occur abnormally in the male. The anomaly varies greatly in degree. (1) The orifice at the base of the glans may persist—the commonest and simplest form. (2) The two halves of the scrotum may fail to fuse in the median plane; either partially or (3) completely, in which case the perineal orifice of the urethra persists.

Extroversion of the Bladder is merely an exaggeration of the condition of epispadias.

The NERVE-SUPPLY OF THE BLADDER is derived mainly from the hypogastric sympathetic plexus (p. 188), and the fibres have their lower centres in the eleventh and twelfth thoracic, the first lumbar, and the second and third sacral segments of the spinal medulla. Reference to the description of the nerve-supply of the large intestine will show that it is also innervated from the same segments.

Vesical Pain.—Referred pains in connexion with the bladder are not uncommon, and their distribution suggests the probability that, whereas the internal trigone is supplied by

the sacral segments, the rest of the bladder is supplied from the lower thoracic and upper lumbar segments of the spinal medulla. For example, when the bladder becomes greatly distended, the internal trigone is little affected, but the other



[*Photo by Alinari.*

FIG. 130.—The Nerve-supply of the Anterior Aspect of the Trunk.

parts of the viscus become more or less stretched. This condition gives rise to referred pain, which is experienced over the lower part of the anterior abdominal wall, *i.e.*, in the areas supplied by the terminal branches of the anterior rami (primary divisions) of the eleventh and twelfth thoracic and

the first lumbar nerves (Fig. 130). On the other hand, when the mucous membrane of the internal trigone is irritated by the presence of a vesical calculus, referred pain is experienced in the perineum and along the penis, *i.e.*, in the areas supplied by the terminal branches of the second and third sacral nerves (Fig. 130).

The Act of Micturition is partly automatic and partly under voluntary control. As the bladder fills, the inhibitory nerves are stimulated and the muscular walls become relaxed, with the exception of the circular fibres which surround the internal urethral orifice, and they, on the other hand, become tonically contracted. As the intra-vesical pressure increases, the afferent nerves of the bladder are stimulated and the micturition reflex is brought into play. This reflex is controlled by a centre in the hypogastric sympathetic plexus (p. 188). So long as the connexions between this centre and the cerebral cortex are intact, the subject becomes conscious of the desire to micturate, and he is able to control it. If, however, the connexions are interfered with, as in fracture dislocations in the mid or upper thoracic region, the act of micturition becomes entirely automatic (p. 48).

A lesion of the lower thoracic or upper lumbar region of the spinal medulla may lead to paræsis of the bladder. In this condition the viscus is able to distend, but is unable to evacuate its contents. Unless the possibility of this condition is recognised, the bladder will become enormously distended, and, eventually, the urine will commence to dribble away. As the nervous mechanism regains control after a short time in some cases, it is important that the damage caused by overstretching of the walls of the bladder should be anticipated and prevented by the periodical passage of a catheter.

Frequency of micturition, with or without straining efforts, is a common symptom in disturbances of the urinary tract. It is necessary to remember, however, that this symptom is the outcome of the presence of a "focus of irritation" (p. 195) in the lumbar region of the spinal medulla, because, although such

a focus is usually set up by pathological conditions of the bladder, it may also arise as the result of abnormal afferent impulses from the large intestine. Frequency of micturition is a frequent accompaniment of irritative conditions of the rectum, and it is not uncommon in connexion with appendicitis (p. 277).

It is interesting to observe that cases of retention of urine are occasionally mistaken for appendicitis, and that the passage of a catheter is sufficient to remove the symptoms.

The Prostate lies between the neck of the bladder and the pelvic surface of the urogenital diaphragm (p. 379) and is traversed by the first part of the urethra. It consists of non-striped muscle fibres, which are continuous with the corresponding coat of the bladder, fibrous tissue and glandular tissue. On each side the prostate is related to the levator prostatæ (the anterior portion of the levator ani, p. 184), and, posteriorly, it is only separated from the anterior aspect of the rectal ampulla by some loose connective tissue. The posterior aspect and the adjoining parts of the lateral surfaces of the prostate can be palpated on rectal examination.

Prostatic hypertrophy may be due to overgrowth of all or any of its constituent tissues. When non-malignant, the condition is only important in so far as it obstructs the outflow of urine from the bladder. In this respect, enlargement of the, so-called, *middle lobe* of the prostate is of great importance. The portion of the organ which gets this name is situated between the ejaculatory ducts and the urethra, *i.e.*, in the upper and posterior part of the prostate (Fig. 127). In some subjects, it projects upwards and forms a small elevation in the internal trigone of the bladder, immediately behind the internal orifice of the urethra. When the middle lobe becomes hypertrophied, the normal elevation becomes larger and is crushed forwards over the internal orifice when the bladder contracts. In these cases, therefore, the patient fails to empty his bladder completely at each micturition. The urine which is left behind is termed the "residual urine," and

it tends to collect in a small, but gradually increasing, pocket behind the enlarged portion of the gland. As the residual urine is very apt to undergo fermentative changes and to set up cystitis, it is a matter of great importance that the patient should make every effort to empty the bladder completely, the expedient of passing urine "on hands and knees" being very useful in this respect in some cases.

The Testis is oval in shape and lies in the scrotum with its upper pole tilted slightly forwards. The two glands do not lie at the same level, and the left one is usually the lower. The **nerve-supply** of the testis is derived from the sympathetic system (L. 1 and 2 ?) and reaches the gland by accompanying the internal spermatic artery. Mackenzie states that a branch of the external spermatic nerve (genital branch of genito-crural) supplies the visceral coat of the tunica vaginalis, which is a portion of the peritoneum that has become shut off from the general peritoneal lining of the abdomen. Referred pain felt in the testis in cases of renal colic is therefore experienced in the terminal fibres of the external spermatic nerve.

The testis receives its **blood-supply** from the abdominal aorta through the internal spermatic artery, which reaches its destination by passing through the inguinal canal as one of the constituents of the spermatic cord. Numerous veins emerge from the testis and ascend along the cord to gain the interior of the abdomen. They constitute the pampiniform plexus, and, owing partly to their dependent position and partly to the absence of valves, they are liable to become varicose. The condition, however, almost invariably occurs on the left side, and no really satisfactory explanation has yet been offered.

The **efferent ducts of the testis** emerge from its upper pole and pass directly into the caput (globus major) of the epididymis, where they unite to form a much convoluted tube.

The Epididymis is an elongated structure, which is closely

applied to the posterior border of the testis. The **caput (globus major)** lies on the upper pole of the testis and is connected to it by the efferent ducts. The **body** and the **tail** are attached to the testis only by connective tissue, and, in rare cases, this attachment may fail, but the condition does

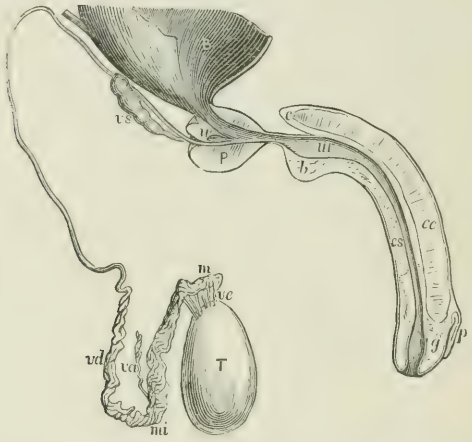


FIG. 131.—Diagram of the Male Reproductive Organs. (TURNER'S *Anatomy*.)

B. Bladder.
P. Prostate.
b. Urethral bulb.
c. Crus penis.
ur. Urethra.
cc. Corpus cavernosum penis.
cs. Corpus cavernosum urethræ.
g. Glans penis.
p. Prepuce.
T. Testis.
ve. Vasa efferentia.
m. Caput of epididymis.
va. Vas aberrans.
mi. Tail of epididymis.
vd. Ductus (vas) deferens.
vs. Seminal vesicle.
u. Prostatic utricle.

not necessitate any abnormality in either structure. The coiled tube of the epididymis emerges from the medial aspect of the tail and ascends along the posterior border of the testis, on the medial side of the epididymis. At the upper pole of the testis, this duct, which is termed the **ductus (vas) deferens**, enters the spermatic cord and ascends to the subcutaneous inguinal (ext. abdom.) ring. In this part of its

course, the spermatic cord is covered only by skin and superficial fascia and it can be grasped between the fingers and thumb. When this is done, no difficulty is experienced in identifying the ductus deferens, for since its muscular wall is very thick in proportion to its lumen, it feels like a solid piece of whip-cord.

The **subcutaneous inguinal (external abdominal) ring** is a gap in the aponeurosis of the external oblique muscle (p. 162), situated above the lateral part of the pubic crest and the medial extremity of the inguinal ligament (of Poupart). It is triangular in outline, the apex being directed upwards and laterally. The size of the ring can be determined by the finger. In order that this may be done, the skin of the scrotum must be invaginated and the finger carried upwards over the front of the pubis. The pubic crest and tubercle having been identified, the finger must then be pressed backwards, when its tip will be found to engage in the subcutaneous inguinal ring. If, after the pubic crest is reached, the finger is carried upwards, it lies between the superficial fascia of the abdominal wall and the external oblique aponeurosis and it can be moved about freely in this stratum.

After entering the subcutaneous inguinal ring, the spermatic cord passes laterally and slightly upwards and backwards in the inguinal canal till it reaches the **abdominal inguinal (int. abd.) ring**, where its constituent parts separate. The **ductus (vas) deferens** descends into the pelvis, crosses the terminal part of the ureter and then descends on the posterior aspect of the bladder, in contact with the duct of the opposite side. As it lies in this situation, it has the **seminal vesicle** to its lateral side. The vesicle is a sacculated diverticulum, which not only acts as a reservoir for the seminal fluid but also possesses a secretion of its own. Inferiorly the vesicle narrows to form a duct, which opens into the ductus deferens at the upper border of the prostate (Fig. 132). In this way, the **ejaculatory duct** is formed, and it passes downwards and forwards through the prostate to open into the prostatic part of the urethra.

Both the ductus deferentes and the seminal vesicles can be palpated through the anterior wall of the rectal ampulla (p. 283), but it is only when they are thickened by inflammatory processes that they can be made out with certainty.

Very little is known about the *nerve-supply* of these structures, but, since the ureter arises from the distal portion of the Wolffian duct (p. 380), the nerve-supply of the ductus deferens, which represents the persistent Wolffian duct (p. 380), must, in its terminal part at least, correspond to the

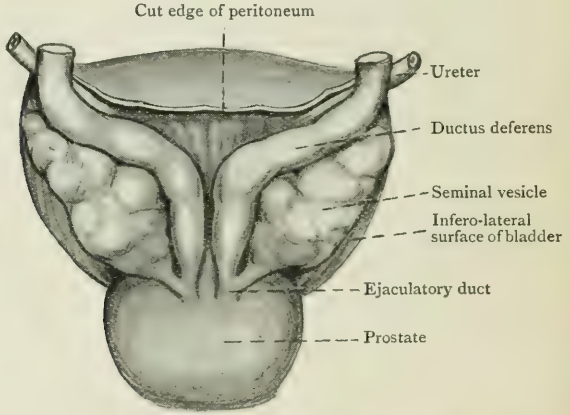


FIG. 132.—The Urinary Bladder and the Prostate, viewed from behind.

nerve-supply of the ureter. The rest of the Wolffian duct arises in the abdomen, and it would appear likely that several segments above the first lumbar take part in the innervation of the ductus deferens. Referred pains in connexion with these structures have not yet been sufficiently studied.

The Urethra begins at the internal orifice at the neck of the bladder and passes downwards and forwards through the prostate. At the apex of the prostate, it pierces the urogenital diaphragm and then enters the bulb of the penis, in which it passes upwards and forwards to the corpus cavernosum

urethræ (corpus spongiosum). This part of the tube is fixed in position, but the cavernous (spongy) part of the urethra, situated within the body of the penis, is freely movable. It is in the most dependent part of the urethra that organisms tend to settle down, and consequently gonorrhœal stricture commonly occurs within the bulb of the penis.

The **prostatic portion** of the urethra (Fig. 127) is the most dilatable part of the canal. A longitudinal elevation, termed the *urethral crest*, is present on its dorsal wall (or floor) and the groove on each side of it receives the openings of the prostatic ducts. Gonorrhœal inflammation may pass backwards into the prostatic urethra, and, if it affects the prostatic duct, a troublesome chronic gleet will supervene. At the anterior end of the urethral crest, there is a small opening in the floor of the urethra. It leads into a short, blind diverticulum, termed the *prostatic utricle* (*sinus pocularis*), which is all that exists in the male as the homologue of the uterus and vagina (Fig. 131). At or near the orifice of the prostatic utricle, the ejaculatory ducts open into the prostatic urethra. They may be infected in posterior urethritis and lead to inflammation of the seminal vesicles or of the epididymis.

The **membranous part** of the urethra lies between the two layers of fascia of the urogenital diaphragm (the two layers of the triangular ligament). It is only half an inch long (Fig. 127), but it is of importance because a false passage may be made with a bougie, in endeavouring to pass the instrument from the cavernous (spongy) part into the membranous urethra.

The **cavernous (spongy) portion** of the urethra is 6 to 8 inches long. It is narrowest at the external orifice on the surface of the glans and is widest within the substance of the glans. A vesical calculus may be passed along the urethra and be unable to pass through its external orifice.

The deep surface of the **prepuce** consists of modified skin and the surface of the glans possesses a similar covering. Normally, after the development of the prepuce is complete,

the skin covering these two surfaces only becomes continuous at the base of the glans and at the frenulum. It often happens, however, that the two opposed surfaces remain adherent to one another in some areas. Such adhesions are capable of producing reflex symptoms, which may vary from enuresis to symptoms closely resembling vesical calculus. The areas of skin involved are supplied by the dorsal nerves of the penis (S. 2, 3 and 4) (p. 184), and it would appear that the adhesions affect their terminal fibres in some way so as to set up a "focus of irritation" (p. 195) within the mid-sacral region of the spinal medulla. This portion of the spinal medulla is accustomed to receive impulses from the internal trigone of the bladder (p. 368), including the ordinary impulses which are interpreted in the cortex as a desire to micturate. The establishment of a "focus of irritation" in this situation will, if sufficiently strong, produce symptoms identical with those in which the internal trigone is irritated by the presence of a vesical calculus. Why such simple adhesions should be capable of causing such violent reflexes has not yet been explained satisfactorily. Simple division of the adhesions removes all the symptoms.

Development of the Epididymis, Ductus Deferens and Testis.—The development of these three structures is intimately associated with the presence of the transitory Wolffian body during early fœtal life.

The **Wolffian Body**, or primitive kidney, is an elongated gland which lies on the posterior abdominal wall. It possesses a longitudinal duct which opens, at its caudal extremity, into the ventral portion of the cloaca (p. 369).

The **reproductive gland**, which at first possesses no sexual characteristics, lies on the ventral aspect of the Wolffian body. In the male, it becomes differentiated into the testis, and its tubules gain a connexion with the **Wolffian Duct**, as the Wolffian body atrophies. This connexion persists and the cephalad portion of the duct develops into the epididymis, while its caudal portion becomes the ductus deferens.

The **Müllerian ducts**, which take an important part in the formation of the reproductive organs in the female (p. 397),

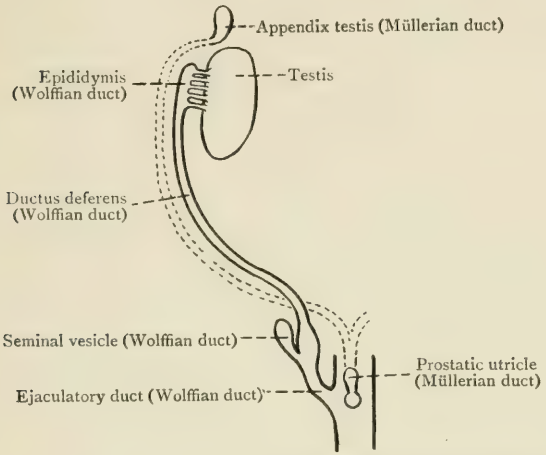


FIG. 133.—The Development of the Male Reproductive Organs.

The dotted lines indicate the main part of the Müllerian duct, which entirely disappears.

disappear almost entirely in the male. Their fused caudal extremities form the prostatic utricle (sinus pocularis, p. 379), while their cephalad extremities are represented by small appendages, which are situated on the upper poles of the testes.

THE FEMALE PELVIS AND REPRODUCTIVE ORGANS

The **Osseous Pelvis** of the female is constructed so as to provide a roomy cavity and wide upper and lower apertures for the passage of the fœtal head. The female pelvis differs from the male pelvis in many ways, but the most important difference is traceable to the sacrum, which is much wider in proportion to its length. As a result, the cavity of the female pelvis may be described as a "short section of a long cone,"

whereas the male pelvis represents a "long section of a short cone."

Congenital anomalies of the sacrum which influence the size of the cavity or the apertures are not of frequent occurrence. Occasionally the ala of the sacrum may fail to develop, and this deficiency causes a marked diminution in the oblique diameter of the pelvis (*Nægele pelvis*). A still rarer anomaly is the congenital absence of both alæ (*Roberts' pelvis*).

At the lumbo-sacral articulation the convexity of the lumbar curve becomes continuous with the concavity of the sacral curve at the **sacral promontory** (Fig. 134). In this situation the vertebral column may be dislocated forwards on the sacrum, as the result of an injury, the real significance of which is often overlooked at the time of the accident owing to the absence of nervous symptoms. As a result of this injury, the antero-posterior diameter of the pelvic inlet is considerably diminished, and the fœtal head is prevented from entering the pelvis (*Spondylolisthetic pelvis*).

Other bony differences distinguish the female from the male pelvis. The pubic crests are longer, and on this account the acetabula have a more lateral inclination. The greater trochanters, therefore, are more widely separated, giving the subject an appearance of increased breadth. The medial slope of the long axis of the femur is greater in the female, and this difference constitutes a slight, but normal, degree of knock-knee.

The available space within the pelvic cavity is increased in the female by the larger size of the pubic arch and of the greater and lesser sciatic foramina. In addition, the spines and tuberosities of the ischium, which tend to encroach on the cavity in the male, are somewhat out-turned in the female.

The following tables, which are taken from Cunningham's *Text-Book of Anatomy*, indicate the measurements of the average female pelvis.

Pelvis Major (False Pelvis)

Maximum distance between iliac crests . . .	$10\frac{3}{4}$ inches
Distance between antero-superior iliac spines . .	$9\frac{3}{4}$,,
Distance between fifth lumbar spine and the front of the pubic symphysis (the external conjugate) .	$7\frac{1}{8}$,,

Pelvis Minor (True Pelvis)

	Upper Aperture.	Cavity.	Lower Aperture.
Antero-posterior diameter .	$4\frac{3}{8}$ inches	$4\frac{3}{8}$ (min.) to 5 inches (max.)	$4\frac{1}{2}$ inches
Oblique diameter . . .	5 inches		$4\frac{1}{2}$ inches
Transverse diameter . .	$5\frac{1}{4}$ inches	$4\frac{3}{8}$ (min.) to $4\frac{7}{8}$ inches (max.)	$4\frac{3}{8}$ inches

These measurements apply to the bony pelvis. The measurements of the pelvis major, however, can be readily carried out on the living subject, and the relation between the interspinous and the intercristal diameters sometimes gives a good indication as to the condition of the pelvis minor. The external conjugate can also be obtained, and, within wide limits, it helps to determine the antero-posterior diameter of the upper aperture (brim). When the measurement exceeds $8\frac{1}{8}$ inches in the living subject, there is no shortening of the latter diameter; on the other hand, when the measurement falls below $6\frac{1}{2}$ inches, the antero-posterior diameter of the upper aperture is definitely diminished.

When the external conjugate falls between these limits, other measurements are required. Of these the most useful is the *diagonal conjugate*. It represents the distance between the inferior aspect of the pubic symphysis and the sacral promontory, and it can be determined on vaginal examination. Under normal conditions, the diagonal conjugate is rather

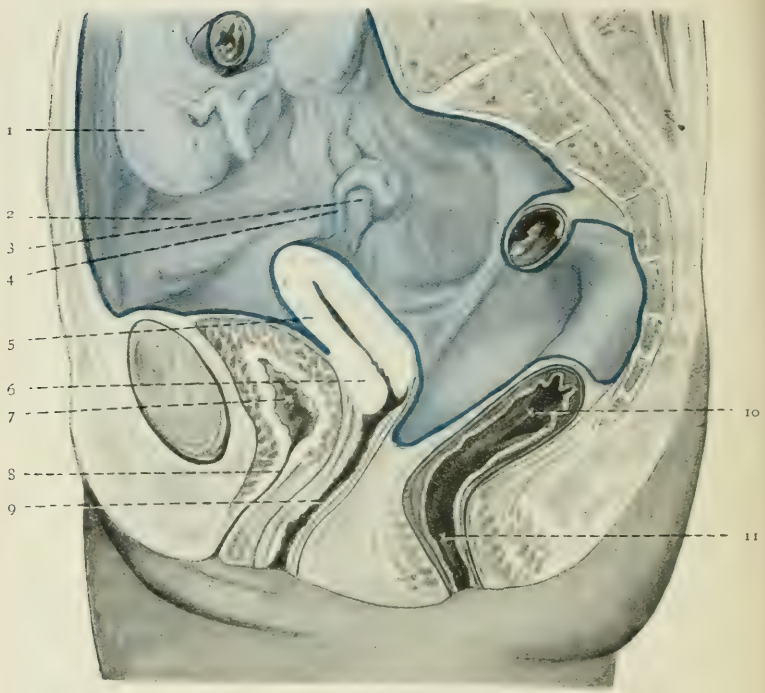


FIG. 134.—Median Sagittal Section through the Female Pelvis, showing the relations of the viscera and the arrangement of the peritoneum, which is indicated in blue. The cut edges of the peritoneum are represented by the dark blue lines.

1. Cæcum.
2. Round ligament of uterus.
3. Ovary.
4. Uterine (Fallopian) tube.
5. Uterus.
6. Cervix uteri.
7. Bladder.
8. Urethra.
9. Vagina.
10. Rectum.
11. Anal canal.

more than half an inch greater than the antero-posterior diameter of the upper aperture.

The **floor of the pelvis** is formed by the *coccygei* and the

levatores ani (p. 184), which separate the pelvis proper from the perineum. In the female, the levator ani supports the lateral walls of the vagina in much the same way as it supports the prostate in the male.

Peritoneum of Female Pelvis.—The arrangement of the **pelvic peritoneum** is of great importance. When a sagittal median section is examined (Fig. 134) it is found that the peritoneum, after covering the upper two-thirds of the rectum, is reflected forwards and comes into relation with the posterior wall of the vagina, *which it clothes in its upper fifth or quarter.* Ascending over the posterior aspect of the uterus, the peri-

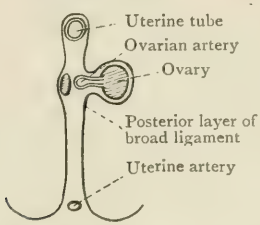


FIG. 135.—Diagram of a Sagittal Section through the Broad Ligament of the Uterus and its contents. The round ligament is shown in contact with the anterior layer of the broad ligament.

toneum is carried forwards on the fundus and then downwards on the anterior aspect. In this position, however, its relation to the uterus is much less complete than on the posterior aspect, for it passes forwards on to the superior surface of the bladder before reaching the cervix (Fig. 134).

It will be seen that there are two well-marked peritoneal fossæ in the female pelvis, which lie, respectively, in front of and behind the uterus. These fossæ are normally occupied by coils of small intestine or of pelvic colon, but they may lodge tumours in connexion with various viscera.

The uterine (Fallopian) tubes extend laterally from the supero-lateral angles of the body of the uterus, and they are related to a fold of peritoneum, termed the **Broad Ligament of**

the Uterus. This arrangement is well seen in Figs. 135 and 136. Fig. 135 represents a sagittal section made immediately to the lateral side of the uterus. It will be seen that the peritoneum on the posterior wall of the pelvis passes forwards on the pelvic floor and then ascends to reach the uterine tube, in this way forming the *posterior layer* of the broad ligament, which is continuous medially with the layer covering the posterior surface of the uterus. After covering the uterine tube, the peritoneum descends anteriorly to the pelvic floor forming the *anterior layer* of the broad ligament, which is similarly continuous with the peritoneum on the front of the uterus. In Fig. 136, the pelvis has been cut transversely, and

FIG. 136.—Diagram of a Transverse Section through the Uterus and the Broad Ligaments, near the lower borders of the latter, showing the relation of the uterine artery to the ureter.

the relation of the peritoneum covering the uterus to the broad ligament is well shown. When the two layers of the broad ligament are traced laterally, they separate from one another and pass forwards and backwards, respectively, on the side wall of the pelvis. It is at this point of separation that the uterine and ovarian vessels enter and leave the broad ligament.

Certain portions of the broad ligament receive special names. (*a*) The part immediately below the uterine (Fallopian) tube is termed the **mesosalpinx**. (*b*) The small fold which connects the ovary to the posterior aspect of the broad ligament is termed the **mesovarium**. (*c*) The **suspensory ligament of the ovary** is that part of the broad ligament which extends between the lateral aspect of the ovary and the side wall of

the pelvis (Fig. 137). It contains the ovarian vessels and nerves, etc.

The Vagina.—The vagina extends upwards and backwards from the genital cleft in the perineum. It is about 3 inches long and, at its upper end, it is attached to the cervix uteri. This attachment is placed at a higher level on the posterior aspect than on the anterior aspect of the cervix. As a result, the posterior wall of the vagina is slightly longer than the anterior wall, and the recess which is caused by the downward projection of the cervix is deeper behind than in front. This recess is termed the **fornix vaginæ**. The *anterior wall* of the vagina is related to the urethra and the posterior surface of the bladder, and this close relationship explains the occurrence of *urethro-vaginal* and *vesico-vaginal fistulæ* and *vesico-celes.*

Posteriorly, the vagina is related to the perineal body, a fibro-muscular node which separates it from the anal canal. At a slightly higher level, the vagina is closely related to the rectum, from which it is only separated by the visceral pelvic fascia. The uppermost part of the posterior wall of the vagina is separated from the rectum by the lowest part of the utero-rectal peritoneal fossa (Fig. 134).

A **Vaginal Examination** gives valuable information about the condition of the pelvic viscera and the contents of the pelvic peritoneal fossæ. The orifice of the vagina is guarded by the *labia majora*, two folds of skin which form the lateral boundaries of the pudendal cleft. When they have been separated, two smaller folds, termed the *labia minora*, are exposed, and care must be taken not to invert these folds into the vagina when the fingers are introduced. Stretching of the inverted labia minora gives rise to acute pain and discomfort. The presence of calculi or other foreign bodies in the urethra or the bladder can be determined by compressing the anterior wall of the vagina against the pubes. In malignant disease of the cervix, palpation of the anterior fornix determines the condition of the bladder, and the possibility of successful surgical interference depends on the freedom of the

bladder from the disease. While the fingers are in the anterior fornix, bi-manual examination will determine whether or not the uterus is in its normal anteflexed and anteverted position.

Through the posterior wall of the vagina, the condition of the rectum can be investigated and a higher level can usually be reached than is possible on examination *per rectum*. Both methods, therefore, should be employed before a diagnosis is arrived at. In addition, palpation of the posterior fornix enables the observer to determine the presence of tumours, exudates, etc., in the utero-rectal fossa.

During the examination, the condition of the cervix uteri and the character of the external os should be noted. In the virgin, the external os feels like a small dimple, but it is an irregularly transverse slit in those who have borne children.

The walls of the vagina are lined by **squamous epithelium**, and the same tissue covers the vaginal portion of the cervix. At the external os, the squamous epithelium merges into the columnar ciliated epithelium of the cervical canal. It follows that malignant disease of the vagina and outer surface of the cervix is of the nature of a squamous-celled epithelioma, which spreads by the lymph stream and does not tend to spread upwards to involve the uterus.

The **lymph vessels** from the lower portion of the vagina terminate in the medial group of the subinguinal lymph glands, which lie below the medial end of the inguinal ligament (of Poupart) on the fascia lata of the thigh.

From the upper part of the vagina, the lymph vessels pass to the external iliac and the hypogastric lymph glands, which lie in relation with the external iliac and the hypogastric (internal iliac) arteries.

Perineal Laceration.—During the delivery of the fœtal head or shoulders, the vaginal wall may be ruptured. The tear invariably involves the lower part of the posterior vaginal wall, since this is the area which is put most on the stretch. The skin of the perineum immediately behind the vaginal opening is torn and the perineal body is involved, in varying

degree according to the extent of the rupture. In a severe case the tear may pass backwards through the perineal body, and both the internal and external sphincters may be divided, as well as some fibres of the levator ani. When, and only when, the internal sphincter is ruptured, incontinence of fæces results.

The condition is as important in view of its remote consequences as it is in view of the possibility of immediate sepsis. Injury to the levator ani muscle lessens the support normally provided for the wall of the vagina and, during defæcation, the anterior wall of the rectum is thrust forwards, bulging into the posterior vaginal wall and carrying it downwards and forwards. Such a bulging may appear at the vulva and is then known as a **recto-cele**. Following this condition, a strain is thrown on the anterior wall of the vagina, which also prolapses through the vulva, sometimes carrying a part of the bladder with it—a **cysto-cele.** As a result, traction is exerted in a downward direction on the uterus, and the utero-sacral ligaments (p. 391) become lengthened. Finally, the cervix itself appears at the vulva and a **complete prolapse of the uterus** is present.

Although perineal lacerations are the most common forerunners of uterine prolapse, there are other factors which assist in its causation. Anything which tends to increase the intra-abdominal pressure—ascites, chronic constipation, etc.—or anything which tends to increase the size of the uterus, will help to produce the condition. In rare cases, the cause may be congenital laxity of the uterine ligaments and the pelvic floor. Such cases are usually accompanied by partial or complete enteroptosis.

On account of these sequelæ, every perineal laceration should be repaired as soon as possible.

The Uterus.—The uterus projects upwards and forwards into the peritoneal pelvic cavity and separates the utero-rectal from the utero-vesical fossa. It measures 3 inches long, 2 inches wide and 1 inch thick. Under normal conditions, the long axis of the uterus meets the long axis of the vagina at an

obtuse angle, which is open ventrally, *i.e.* the uterus is *anteverted* (Fig. 134). In addition, the body of the uterus is bent forwards on the cervix, so that the normal uterus is not only anteverted but also *anteflexed.*

The uterus consists of a narrow, lower portion, termed the **cervix**, which is continuous above with the **body.** The free, upper extremity of the body of the uterus is known as the *fundus*, and, at the junction of the lateral margin of the body

FIG. 137.—The Uterus and the Broad Ligaments, viewed from in front. (TURNER'S *Anatomy.*)

b. Body of uterus.
bl. Broad ligament.
c. Cervix uteri.
f. Fundus uteri.
o. Ovary.
p. Ep-oöphoron.
r. Round ligament.
t. Uterine (Fallopian) tube.

with the fundus, the uterus is joined by the **uterine (Fallopian) tube.**

The **Cervix Uteri** is about 1 inch long. Its lowest part projects into the cavity of the vagina and is consequently termed the *vaginal portion.* The *intra-mural portion* of the cervix receives the attachments of the vaginal walls, while the *supra-vaginal portion* projects upwards above the vagina. It should be observed that, whereas the supra-vaginal portion of the cervix is covered by peritoneum on its posterior aspect, it receives no such covering on its anterior aspect, which is only separated from the bladder by some connective tissue.

The **Body of the Uterus** is related, anteriorly, to the bladder

and the contents of the utero-vesical peritoneal fossa and, posteriorly, to the rectum and coils of small intestine or pelvic colon. The lateral border of the body is related to the broad ligament and to the uterine artery (p. 392).

The Ligaments of the Uterus.—In addition to the **broad ligaments** (p. 385), the uterus is more or less fixed in position by two **round ligaments** and two **utero-sacral ligaments.** The **round ligament** is a fibro-muscular band, which is attached to the uterus near the point where it is joined by the uterine tube. It passes downwards and laterally between the two layers of the broad ligament and reaches the abdominal inguinal ring (int. abdom. ring, p. 377), where it enters the inguinal canal. Just outside the subcutaneous inguinal ring (ext. abdom. ring) the round ligament is attached to the skin and fascia in the neighbourhood of the pubic tubercle (spine). By exerting a certain slight amount of traction on the upper part of the body of the uterus, the round ligament assists in maintaining the normal position of the organ. Consequently, one of the surgical procedures adopted in the treatment of retroversion of the uterus is *shortening of the round ligaments.*

The **utero-sacral ligaments** are attached to the posterior aspect of the lower part of the body of the uterus and they extend backwards, raising ridges on the peritoneum, on each side of the rectum. By exerting slight backward traction, these ligaments maintain the normal degree of anteflexion, but, if they become contracted and shortened following inflammatory processes, they produce acute anteflexion of the uterus by drawing backwards the point of union of the body of the uterus with the cervix. In this displacement, the contractions of the uterus cannot readily expel the contents during menstruation and the contractions become more violent, giving rise to referred pains which may be exceedingly severe.

Displacements of the Uterus.—In addition to acute anteflexion, **retroversion,** with or without some degree of **retroflexion,** may also occur. These conditions are only possible when the utero-sacral and round ligaments are

abnormally lax, and they give rise to the same symptoms of referred pain as acute anteflexion. If, however, the retroverted uterus becomes pregnant, as the organ enlarges it is caught below the promontory of the sacrum and prevented from ascending into the abdomen. Under these circumstances, the enlarging uterus exercises pressure on the other pelvic viscera, which cannot get out of the way as they are anchored in position by the peritoneum. Constipation is present but does not necessarily attract the patient's attention. On the other hand, frequency of micturition becomes very oppressive and warns the patient that all is not well. If the retroverted gravid uterus is replaced in the normal position of anteversion,

FIG. 138.—Diagram of a Transverse Section through the Uterus and the Broad Ligaments, near the lower borders of the latter, showing the relation of the uterine artery to the ureter.

the pregnancy will then in all probability pass to full time, but, unless this is effected, abortion at or shortly after the third month is inevitable.

The BLOOD-SUPPLY OF THE UTERUS is derived from the **uterine** and the **ovarian arteries** (p. 395). The uterine artery arises from the hypogastric (internal iliac) and runs forwards across the floor of the pelvis till it reaches the base of the broad ligament. It then turns and runs medially in the lowest part of the broad ligament, and three-quarters of an inch from the uterus it crosses above and in front of the ureter, as the latter passes forwards to reach the bladder. On reaching the lateral aspect of the cervix, the uterine artery gives off a small, descending vaginal branch and turns upwards along the lateral border of the uterus to supply the organ. In the operation of

hysterectomy, ligature of the artery is carried out in the interval between the point where it crosses the ureter and the point where it gives off its vaginal branch. The greatest care must be taken to avoid including the ureter in the ligature. The pulsations of the uterine artery may be felt when the fingers are examining the lateral vaginal fornix.

The Lymph Vessels from the body and fundus of the uterus terminate in the lumbar and the external iliac lymph glands for the most part, but a few pass along the round ligament and reach the superficial subinguinal group (p. 388). The lymph vessels from the cervix pass to the hypogastric and the external iliac lymph glands (p. 388) and also to the lymph glands which lie on the anterior aspect of the sacrum.

The Nerves of the Uterus are mainly derived from the hypogastric plexus of the sympathetic, and they are ultimately derived from the lower three thoracic and the first lumbar segments and the second, third and fourth sacral segments. The relation of the viscero-sensory reflex of Mackenzie to uterine pain has not been at all fully worked out. When the uterus gives rise to referred pains, they are usually experienced in the regions supplied by the posterior rami of the lower thoracic nerves (Fig. 60), but the areas supplied by the anterior rami are sometimes affected. As in the case of other viscera supplied from the sacral part of the spinal medulla, referred pains are usually experienced in the perineum and only very rarely in the lower limb.

The Ovary.—The ovary lies between the two layers of the broad ligament and projects backwards from the posterior layer (Fig. 135). Some authorities do not regard the ovary as lying between the two layers, on the ground that its surface is covered not by peritoneal endothelium but by *germinal epithelium*. The small fold which connects the ovary to the posterior layer of the broad ligament and transmits its vessels and nerves is termed the mesovarium. In the nullipara the ovary lies with its long axis nearly vertical in a small peritoneal depression, the *fossa ovarica*, on the side of the pelvis. In

this situation the lateral surface of the ovary is related to the obturator nerve, which runs forwards extra-peritoneally across the floor of the fossa ovarica. Pelvic inflammation in this region may result in pressure on the obturator nerve and referred pain may be experienced along the medial side of the thigh (Fig. 7).

The medial surface of the ovary is related to the uterine (Fallopian) tube, which is attached by one of its fimbriæ to the upper ovarian pole. The lower pole of the ovary is

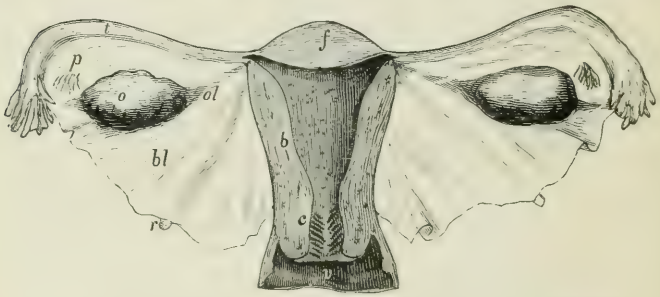


FIG. 139.—The Broad Ligaments of the Uterus, viewed from behind. The uterus has been cut in a frontal (coronal) plane. (TURNER'S *Anatomy*.)

b. Body of uterus.
bl. Broad ligament.
c. Cervix uteri.
f. Fundus uteri.
o. Ovary.
ol. Ovarian ligament.
v. Vagina.
p. Ep-oöphoron.
r. Round ligament.
t. Uterine tube.

attached to the upper lateral angle of the uterus by a fibro-muscular band, which is termed the **ligamentum ovarii proprium.** In pregnancy the ovary is carried upwards with the enlarging uterus out of the pelvis into the abdominal cavity, but its relation to the broad ligament does not undergo any important alteration. On the other hand, when cysts develop in the ovary, the organ ascends from the pelvis but it remains anchored to the broad ligament by the **mesovarium** (p. 386), which becomes somewhat elongated to form the pedicle of the cyst. This pedicle contains the nerves, lymph and blood-vessels of

the ovary, and the last-named are naturally much increased in size. Owing to the constant alteration of the positions of many of the abdominal viscera, the ovarian cyst may be twisted on its pedicle in such a way as to cut off its blood-supply. This condition at once produces symptoms which are similar to those arising in cases of strangulated hernia. The similarity of the symptoms is due to the similarity in nerve-supply, for both viscera are supplied by sympathetic fibres which have their origin in the lower thoracic segments. In this connexion it is interesting to observe that in certain cases the differential diagnosis between pain induced by inflammation of the vermiform process (appendix) and pain having its origin in the right ovary may be extremely difficult.

The **Ovarian Artery** arises from the abdominal aorta and descends to the pelvis on the surface of the psoas major. It enters the broad ligament by passing between the two layers of the suspensory ligament of the ovary at a point where they separate from one another on the lateral wall of the pelvis (Fig. 138). Running medially, it supplies branches to the uterine (Fallopian) tube, some of which extend medially to anastomose with the uterine artery, but the main part of the ovarian artery enters the mesovarium to reach the hilum of the ovary. When the ovaries and tubes are removed together with the uterus, ligature of the uterine and ovarian vessels is one of the first steps of the operation. The latter are secured by clamping the suspensory ligament of the ovary.

The *ovarian lymph vessels* terminate in the lumbar lymph glands.

The Uterine (Fallopian) Tube.—The uterine tube lies in the upper border of the broad ligament, but its lateral extremity projects freely into the pelvic cavity. This extremity of the tube is more or less funnel-shaped, and the walls of the funnel are formed by a number of narrow processes, termed the **fimbriæ**. One of these fimbriæ is attached to the upper pole of the ovary, so that the two structures are never far removed from one another. At the bottom of the

funnel is a small opening, the **ostium abdominale**, through which the lumen of the tube communicates directly with the peritoneal cavity of the pelvis, and at the margin of the orifice the endothelium of the peritoneum merges into the columnar ciliated epithelium of the tube.

When **ovulation** occurs and an ovum is discharged from the ovary, it passes at once into the general peritoneal cavity. If it does not come into contact with one of the fimbriæ, it is absorbed, but if it does do so, it may succeed in entering the ostium abdominale and it is then carried medially towards the uterus by the action of the ciliæ lining the uterine tube. According to current beliefs, the ovum, if it is destined to become fertilised, undergoes that change within the tube and is then carried onwards into the uterine cavity, which is ready to receive it by the time it leaves the tube.

Ectopic Gestation.—Under abnormal conditions, the impregnated ovum may fail to reach the uterus, and, in that event, it goes on developing in the tube, giving rise to the **tubal type of ectopic gestation**. As the ovum enlarges, the wall of the tube becomes gradually thinned out, and between the sixth and eighth week it ruptures. The seriousness of the condition depends on the exact site of the rupture. If the rupture involves the upper surface of the tube, the peritoneum covering it is also affected, and an intra-peritoneal hæmorrhage occurs which calls for instant surgical interference. On the other hand, the lower surface of the tube may rupture and, in this case, the subsequent hæmorrhage occurs between the two layers of the broad ligament. As a result, it is more restricted in amount and the condition, though by no means trivial, is not so serious.

Just as the ostium abdominale allows the passage of the ovum from the peritoneal cavity into the uterine tube, so it may permit septic infection to spread directly from the tube to the peritoneal cavity and, indeed, by way of the vagina, uterus and uterine tube, infection may ascend from the exterior to the pelvic peritoneal cavity. The presence of

pus in the utero-rectal fossa can always be determined by palpation of the posterior fornix of the vagina.

Congenital Anomalies of the Female Pelvic Viscera. —Before the various congenital anomalies are described, it is necessary to give a brief outline of the normal developmental history of the female organs of generation.

The **Müllerian ducts**, which leave very few remains in the male (p. 381), form practically the whole of the uterine tubes, the uterus and the vagina. Their mode of origin is curious, as the ostium abdominale is the first part to appear. A surface depression occurs in the lining membrane of the body cavity,

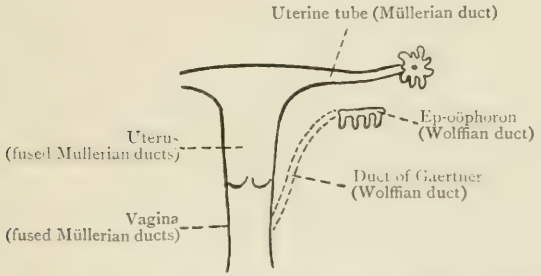

Uterine tube (Müllerian duct)
Ep-oöphoron (Wolffian duct)
Uterus (fused Mullerian ducts)
Duct of Gaertner (Wolffian duct)
Vagina (fused Müllerian ducts)

Fig. 140.—Diagram of the Development of the Female Generative Organs.

The dotted lines represent the part of the Wolffian duct which normally disappears.

lateral to the Wolffian body (p. 380), and it burrows its way tailwards, still retaining its connexion with the body cavity—a connexion which, as already noticed, exists throughout life. After a time, the two Müllerian ducts approach one another by passing medially in front of the Wolffian duct and the gut, and their caudal portions unite. About this time the caudal end of the tube opens into the urogenital sinus, but, later, owing to a difference in the relative rates of growth, the urethra and the vagina acquire independent orifices on the surface of the perineum.

The proximal unfused ends of the Müllerian ducts form the uterine tubes; the fused portions form the uterus and vagina.

The process of fusion may not be carried out in its entirety, and varying degrees of failure are found. In the simplest variety, the vagina is subdivided into right and left halves by a median partition, and the condition may or may not be associated with a **bicornuate** or **bipartite uterus.** The possibility of the presence of a bicornuate uterus must always be borne in mind in obstetrical and gynecological practice, as it is by no means a great rarity.

The ovary is developed from the reproductive gland (p. 380), which arises in the lumbar region in close relation to the kidney. As a result, it obtains its blood-supply direct from the abdominal aorta and its nerves from the lower thoracic part of the spinal medulla. It is not till the later stages of fœtal life that the ovary becomes pelvic in position. Although in this way striking similarities exist between the testis and the ovary, yet malposition of the ovary is extremely rare as compared with malposition of the testis.

The **Ep-oöphoron** (**Parovarium**), which lies in the broad ligament below the uterine tube, is a vestigial structure. It represents a few persisting tubules of the Wolffian body. These tubules open into a longitudinal duct, which is usually blind at both extremities, but which may descend along the lateral margin of the uterus, subsequently opening into the vagina. It is termed the *duct of Gaertner*, and it represents the persisting part of the Wolffian duct. The ep-oöphoron may be the site of cystic enlargement, and such enlargement occurs between the two layers of the broad ligament. If the tumour is a large one, the uterine tube is found to be stretched across its superior aspect and the ovary is attached to its posterior aspect by means of the mesovarium, which, however, may practically be incorporated with the peritoneal covering of the tumour.

The **Female Bladder** differs slightly from the corresponding organ in the male with regard to its position. Owing to the absence of the prostate, the neck of the bladder comes into relation with the upper fascia of the urogenital diaphragm

(deep layer of the triangular ligament), and it, therefore, occupies a lower position, but in size and shape there is little difference. The superior aspect of the bladder is normally in relation to the anterior surface of the uterus, but the utero-vesical pouch of the peritoneum intervenes. On the other hand, the posterior surface of the bladder is in direct contact with the anterior aspect of the supra-vaginal part of the cervix and the anterior wall of the vagina (Fig. 134).

The **urethra**, in the female, is only 1 to 1½ inches long, and as it passes from the internal to the external orifice it follows a slightly curved course, the concavity of the curve being directed forwards. The tube is remarkable owing to its dilatability. Stones of large size may be passed *per urethram*, and the channel can be dilated so as to render direct examination possible both of the vesical mucosa and of the ureteral openings. The external orifice of the urethra lies about 1 inch posterior to the clitoris and immediately in front of the orifice of the vagina. Both lie between the labia minora.

The *para-urethral glands* lie in the submucous tissue of the urethral wall. They are of interest because, though small, they are believed to be homologous with the glandular tissue of the prostate. They open on the surface by a single duct, on each side, just lateral to the external orifice of the urethra.

VII

THE DUCTLESS GLANDS

UNDER the heading of the ductless glands are included the **hypophysis** (**pituitary body**), the **thyreoid**, the **parathyreoids**, the **glomus caroticum** (**carotid body**), the **thymus**, the **spleen**, the **supra-renals** and the **glomus coccygeum** (**coccygeal body**). It must be remembered, however, that many of the glands which possess ducts do not excrete all their secretion through these ducts, and that a part of their secretion is carried away by the blood-stream. In this way, the ovary, testes, pancreas, etc., all behave after the manner of ductless glands. Further, although, like other parts of the body, they are subject to numerous pathological changes, the nature of their secretions may be so changed as to alter their controlling influence without producing any recognisable change in the gland itself. On the other hand, such grave conditions as exophthalmic goitre and splenic anæmia are accompanied by striking alterations in the glands concerned.

The Hypophysis (Pituitary Body).—The hypophysis lies in a fossa on the superior aspect of the body of the sphenoid. Above, it is attached by a small stalk to the tuber cinereum in the interpeduncular fossa (p. 16), and it is partially roofed in by a small process of dura mater (Fig. 56). This connexion with the brain indicates in part the development of the gland, for its **posterior lobe** develops as a down-growth from the floor of the third ventricle. The **anterior lobe** develops as an up-growth from the roof of the pharynx, with which it soon loses all connexion. It was formerly

believed that only the anterior lobe of the hypophysis was functionally active, but it is now known that the posterior lobe also possesses an internal secretion.

On each side, the hypophysis is related to the cavernous sinus and the important structures which are contained in its walls (p. 116), namely, the third, fourth, ophthalmic division of the fifth, and the sixth cerebral nerves and the internal carotid artery. Anteriorly, the hypophysis is related to the

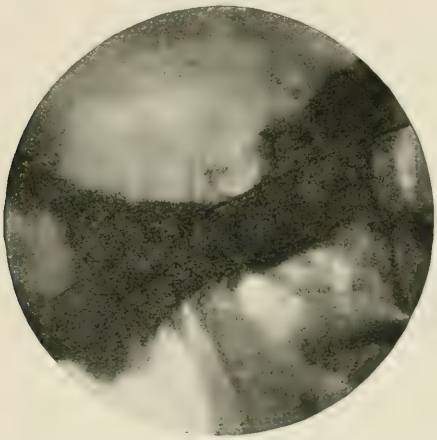


FIG. 141.—Radiogram of Skull, showing a normal hypophyseal (pituitary) fossa. (From KNOX'S *Radiography*.)

optic chiasma (Fig. 8). These relations are of importance, as the results of pressure upon them may be of great help in the diagnosis of enlargement of the gland. In the majority of cases of **acromegaly** in which the hypophysis has been examined, it has been found to have undergone some pathological change, frequently of the nature of tumour growth. The optic chiasma is most commonly affected, and cases of *bitemporal hemianopia* are usually due to this cause; crossed hemianopia or binasal hemianopia may also occur. Affections

of the third, fourth and sixth nerves, or of combinations of these nerves, especially when the paralysis is bilateral, should, in the absence of basal meningitis, suggest the possibility of enlargement of the hypophysis.

Inferiorly, a thin plate of bone separates the hypophysis from the sphenoidal air-sinuses (Fig. 114), and, when the gland

FIG. 142.—A much enlarged Hypophyseal Fossa, caused by a tumour of the Hypophysis (pituitary body). (From a Radiograph taken by Dr. S. G. SCOTT.)

enlarges, this plate becomes so thin that it can easily be removed during the operation of excision of the gland. The sphenoidal sinuses act as a convenient landmark in lateral radiograms of the skull, and the hypophyseal fossa can usually be made out without great difficulty. In those cases in which the optic chiasma is affected, an increase in the antero-posterior extent of the fossa may be expected, but when the tumour grows in a lateral direction, no sign of alteration may be found in radiograms of the skull.

The Spleen.—The spleen lies mainly in the left hypochondriac region, in contact with the left cupola of the diaphragm. Under normal conditions it is exceedingly pliable, and its shape is moulded according to the pressure exerted by the stomach and the left (splenic) flexure of the

FIG. 143.—The Spleen and the Left Kidney and Ureter outlined on the Dorsal Aspect of the Body. The lower border of the left lung and the lower limit of the left pleural sac are also shown.

colon, which wedge it against the diaphragm and the left kidney. With the exception of a small strip at the hilum, it is entirely covered by the peritoneum of the greater sac, and it is attached to the fundus of the stomach and the anterior surface of the left kidney by the gastro-splenic and the lieno-renal ligaments, respectively (Fig. 144).

The **diaphragmatic surface** of the spleen is gently convex,

and possesses superior, anterior and posterior angles. The superior angle is only $1\frac{1}{2}$ to 2 inches lateral to the median plane and is on a level with the tenth thoracic spine. The anterior angle lies in the ninth intercostal space in the posterior axillary line, while the posterior angle lies on the eleventh rib. This surface, in its whole extent, is separated by the diaphragm from the lower part of the left pleural sac, and its upper part is also under cover of the lower border of the left lung. Percussion of the diaphragmatic surface of the spleen is rendered exceedingly difficult on account of the number of structures which intervene between it and the surface of the body. They include the diaphragm, the pleural sac, the thoracic parietes, the latissimus dorsi muscle and, over the superior part, the lung and the sacro-spinalis muscle, in addition. It should be remembered that, *when the spleen is normal in size and position, it cannot be palpated*, as it lies under cover of the left costal margin, and that only its anterior half can be determined by means of percussion.

The **anterior border** of the spleen extends from the superior to the anterior angle and it almost invariably possesses one or more **notches** (Fig. 125). These notches may be of help in determining the nature of a tumour on the left side of the abdomen (*vide infra*).

The **gastric surface** of the spleen is separated from the diaphragmatic surface by the anterior notched border, and from the **renal surface** by the hilum. The **inferior surface** of the spleen is in contact with the left flexure of the colon and with a peritoneal fold, termed the **phrenico-colic ligament**, which extends from the flexure to the diaphragm. This fold is of great importance to the clinician, for it accounts for the direction in which the spleen passes as it enlarges. It prevents enlargement in a purely downward direction, and makes the organ pass forwards and downwards.

Splenic Enlargement.—As the spleen enlarges, the diaphragmatic surface increases in extent until it projects beyond the costal margin and comes into contact with the muscular anterior

abdominal wall. But the anterior angle can be palpated while it is still under cover of the ribs by pressing upwards and backwards during expiration. When it leaves the costal margin, the spleen passes obliquely across the abdomen in direct contact with the anterior wall so that it can be both palpated and percussed very easily. The obliquity of the anterior border of a tumour in the left half of the abdomen and the presence upon it of one or more notches is sufficient to justify the diagnosis of splenic enlargement.

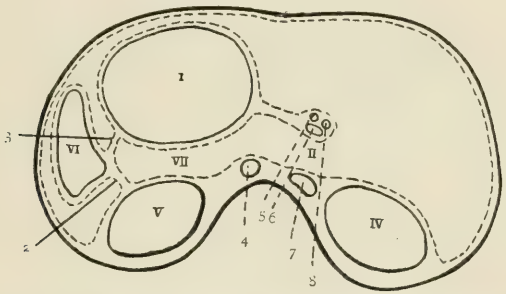


FIG. 144.—Transverse Section through the Abdomen at the level of the epiploic foramen (of Winslow), to show the disposition of the peritoneum and the connexions of the spleen.

In this section the stomach is cut along the line A (Fig. 89).

I. Stomach.
II. Epiploic foramen.
IV. Right kidney.
V. Left kidney.
VI. Spleen.
VII. Omental bursa (lesser sac).
2. Lieno-renal ligament.
3. Gastro-splenic ligament.
4. Aorta.
5. Hepatic artery.
6. Portal vein.
7. Inferior vena cava.
8. Bile duct.

The dulness produced by an enlarged spleen may merge with the liver dulness, but a Λ-shaped notch can usually be demonstrated between the two viscera.

In rupture of the spleen it is usually the diaphragmatic surface which is involved, and the hæmorrhage occurs directly into the greater peritoneal sac (Fig. 144).

The spleen obtains its **blood-supply** from the *splenic artery*, which is one of the branches of the cœliac artery. The

splenic vein receives tributaries from the stomach and the pancreas, and, near its termination, it is joined by the inferior mesenteric vein. Finally, it unites with the superior mesenteric vein to form the vena portæ. In portal obstruction, the splenic vein shares in the obstruction, and the resulting *venous congestion of the spleen* causes definite enlargement of that organ (p. 274).

In addition to pouring its blood into the portal circulation, the spleen undergoes slow, rhythmic contractions, which greatly assist the flow of blood through the portal system. These contractions occur once per minute and they disappear altogether when the spleen becomes enlarged. Very little is known with regard to the mechanism by which the contractions are controlled, but, when the organ becomes increased in size, the contractions either diminish or disappear entirely, so that they are of little help from the point of view of diagnosis.

Movable spleen, though uncommon, is a well-recognised condition. It usually occurs in association with complete visceroptosis (cf. p. 389), and is due to the increased extent and laxity of its peritoneal connexions, namely, the gastro-splenic and the lieno-renal ligaments. The condition, *per se*, is of little or no importance, but it may be accompanied by pain due to stretching of the peritoneum (cf. movable kidney, p. 360). It sometimes happens that the lieno-renal ligament becomes twisted and this produces kinking of the contained splenic vein. As a result, the organ becomes greatly distended and the condition is apt to be mistaken for an ovarian cyst with a twisted pedicle. The mistake, however, is of little consequence, since both conditions call for immediate surgical interference.

The operation of *complete splenectomy* has been carried out for movable spleen and after rupture of the viscus, and it is not followed by any grave disturbance in the general state of health.

Puncture of the Spleen.—When it is desired to obtain a specimen of the blood in the interior of the spleen, a hypo-

dermic needle may be passed into its substance without any bad after-effects. As a general rule, under these circumstances, the organ is enlarged and its diaphragmatic surface, being in direct contact with the anterior abdominal wall (p. 405), may be reached without the risk of injuring any of the neighbouring viscera.

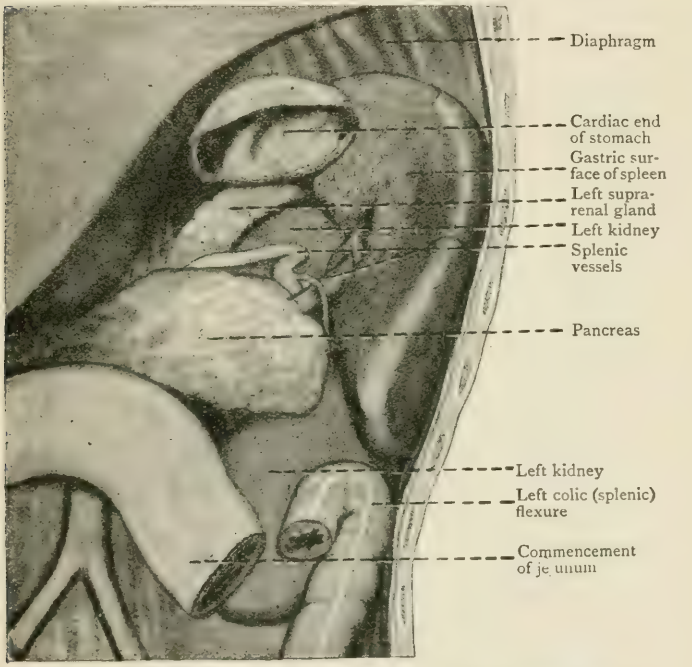


FIG. 145.—The relations of the Left Kidney and the Viscera, which form the "bed" of the Stomach.

The Supra-renal Glands.—The supra-renal glands lie on the upper part of the posterior abdominal wall. They are closely related to the upper poles of the kidneys, from which they are separated only by a little loose areolar tissue. This relationship, however, is purely topographical, for the develop-

mental histories of the two viscera are very different. As has already been pointed out, the kidneys originally develop in the pelvic region, and the retention of the pelvic position is a well-recognised developmental anomaly. On the other hand, the supra-renal glands develop in the abdomen, and they are therefore found in their normal position on the posterior abdominal wall, even when the kidney lies in the pelvis. Histologically, the supra-renal gland consists of two parts, which are well differentiated, namely, the **cortex** and the **medulla**. These two parts differ from one another, not only in appearance, but also in their functions and their mode of development. Adrenalin is formed in the medulla of the gland, while the cortex is functionally passive, and cortical extracts have no marked actions, when introduced into the body. The medulla of the supra-renal is developed by a budding off of some of the cells of the lumbar sympathetic system, whereas the cortex is simply a condensation of the mesoderm, in which the medullary *anlage* is situated. This connexion of the gland with the sympathetic system is of interest in connexion with Addison's disease.

In the majority of cases, post-mortem examination in **Addison's disease** has revealed some lesion, usually tuberculous in origin, of the supra-renal glands. In a small percentage of cases, the supra-renals have been normal in appearance and structure, but examination of the cœliac ganglia (p. 188), which lie close to the medial borders of the supra-renals, has revealed the fact that they were the site of tuberculous disease. In consequence, there are two different theories with regard to the cause of Addison's disease. The first, and most widely accepted, theory holds that the condition is due to some pathological change in the supra-renal glands, and that this change leads to alteration in the nature of the internal secretion. This theory infers that the administration of supra-renal extract is the rational line of treatment to adopt. The use of this extract, though sometimes temporarily beneficial, cannot, however, be regarded as

curative. The second theory holds that the abdominal sympathetic is at fault, and that the occurrence of the disease, along with pathological conditions of the gland, is due to the formation of adhesions with, and consequent irritation of, the cœliac ganglia and their branches.

The Thyreoid Gland.—The thyreoid gland is, perhaps, the most important of all the ductless glands, since it is the most frequently affected by pathological conditions. It consists of two **lateral lobes** connected to one another by a narrow band of gland substance, termed the **isthmus** (Fig. 146). The isthmus lies in front of the second, third and fourth rings of the trachea, and, like the rest of the gland, it is enveloped in a fibrous sheath, derived from the pretracheal layer of the deep cervical fascia.

The lateral lobe is pyramidal in shape. The pointed *apex* is superior and lies in contact with the lamina of the thyreoid cartilage. The enlarged *base* is inferior and extends downwards to the level of the sixth or seventh tracheal ring. The deep surface of the lateral lobe is in contact with the thyreoid and cricoid cartilages and the upper six or seven rings of the trachea, but it usually extends farther backwards and comes into relationship with the inferior constrictor of the pharynx and the œsophagus. Its lower part, therefore, is related to the recurrent (laryngeal) nerve, which ascends in the groove between the trachea and the œsophagus and disappears under cover of the inferior constrictor (Fig. 49).

Tumours of the Thyreoid Gland.—When the thyreoid gland becomes enlarged, the effects are mainly produced on the deep relations. There may be *difficulty in respiration* owing to pressure on the trachea, but, owing to the strength of the tracheal walls, this symptom may be preceded by *dysphagia*. In addition, one or both recurrent nerves may be involved, and irritation of them leads to *unilateral* or *bilateral abductor paralysis* (p. 338). Section of the thyreoid isthmus is sufficient to do away with the respiratory embarrassment, since it removes the constricting band.

The antero-lateral surface of the gland is placed under cover of the sterno-thyreoid, sterno-hyoid and omo-hyoid muscles. These muscles become stretched out, forming a thin sheet over the gland when it is enlarged. On this

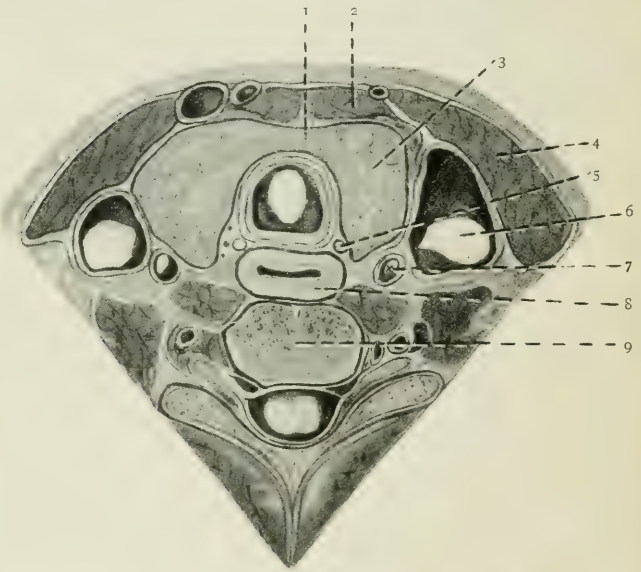


FIG. 146.—Transverse Section through the Neck at the level of the First Thoracic Vertebra.

1. Isthmus of thyreoid gland.
2. Sterno-hyoid and sterno-thyreoid muscles.
3. Right lobe of thyreoid gland.
4. Sterno-mastoid muscle.
5. Right recurrent nerve.
6. Internal jugular vein.
7. Common carotid artery.
8. Œsophagus.
9. First thoracic vertebra.

account, the gland becomes very superficial and can readily be palpated.

The posterior surface of the gland overlaps the antero-medial aspect of the carotid sheath, which may be thrust deeply under cover of the sterno-mastoid when the gland is

enlarged. In some cases, tumours of the thyreoid may transmit the pulsations of the carotid artery.

The **internal secretions** of the thyreoid gland are of the greatest importance in controlling and regulating the tissue-changes of the body. Congenital absence of the gland causes the condition of *cretinism*, in which the subject is backward in growth, both mentally and bodily. *Myxœdema* arises when the secretions of the thyreoid, hitherto normal in character and sufficient in amount, undergo alterations, leading to changes in both the mental and the physical conditions of the patient. These involve a curious overgrowth of the superficial fat in certain regions of the body, notably in the face and in the lower part of the posterior triangle of the neck. The opposite condition, *thyreoidism*, is most frequently seen in exophthalmic goitre. It is also met with after operations which have involved incisions into the gland, and it then arises from absorption of the secretion which is poured out from the cut surface. The condition is characterised by a rapid and weak pulse, rapid and shallow respirations, tremor and other signs of great nervous excitability. It is said that removal of the thyreoid gland alone does not cause myxœdema, and it is suggested that the parathyreoids (p. 412), if left behind, are able to carry out all the duties of the thyreoid gland.

Development of the Thyreoid Gland.—The thyreoid gland arises as a downward-growing hollow bud in the floor of the primitive pharynx, and its connexion with the mouth remains as the *foramen cæcum*, a small blind pit situated in the middle line on the dorsum of the tongue, at the junction of its middle and posterior thirds. The bud grows downwards in front of the larynx, loses its lumen and enlarges to form the isthmus and the lateral lobes. The connexion between the foramen cæcum of the tongue and the isthmus of the thyreoid is known as the **thyreo-glossal duct**, and it may persist either in a part or in the whole of its extent. When persistent, it may give rise to a *thyreo-glossal cyst*, which may extend

upwards above the hyoid bone into the substance of the tongue. Such cysts lie superficial to the larynx and are easily felt in the anterior median line of the neck. They may lie superficial to the hyoid bone, but, as the thyreo-glossal duct frequently passes through the hyoid bone, they may be constricted at this point.

The thyreoid gland receives two *arteries* on each side. The *superior thyreoid*, which arises from the external carotid, is chiefly distributed to the upper pole and the upper border of the isthmus, while the *inferior thyreoid*, which arises from the first part of the subclavian artery, supplies the lower two-thirds of the lateral lobe and the inferior border of the isthmus. The *superior* and *middle thyreoid veins* pass laterally to join the internal jugular vein, but the *inferior group* descend in front of the trachea to terminate in the left innominate vein. The position of the latter group is of great importance in connexion with the operation of low tracheotomy, on account of the danger of the inspiration of blood into the terminal bronchi.

The *lymph vessels of the thyreoid gland*, for the most part, terminate in the lower anterior group of the deep cervical lymph glands (p. 352), but some of them descend along the trachea and join the paratracheal and the mediastinal lymph glands.

The **Parathyreoid Glands** are four in number. They lie within the fascial sheath of the thyreoid gland in close relation to the posterior aspects of the lateral lobes, and it is believed that they are able to assume and carry on the functions of the thyreoid gland after thyreoidectomy. It has also been suggested that the parathyreoid glands are at fault in tetany and in paralysis agitans.

The Thymus Gland.—The thymus gland lies in the lower part of the neck and in the superior mediastinum. Its history is complicated by the numerous variations which may occur from what is believed to be the normal standard. At birth the gland is relatively large and is responsible for the large area of dulness which is found on percussion over the upper

part of the sternum. It enlarges fairly rapidly during the first few years of life, but from infancy to the onset of puberty its rate of growth is much slower. Thereafter it rapidly decreases, and, in adult life, it may be represented merely by a few fibrous strands in the superior mediastinum. It must be remembered, however, that it is by no means uncommon for the thymus gland to retain its original size throughout life, and this condition is much commoner in females than it is in males.

Tumours of the Thymus Gland.—Even the fibrous remnants of the gland may give rise to a *mediastinal tumour*, and such a condition is frequently found in exophthalmic goitre. The symptoms depend on the relations of the gland. Venous engorgement is commoner on the left side of the head and neck and upper limb, as the gland lies anterior to the left innominate vein. Since the gland lies immediately behind the manubrium sterni, the area of dulness to which it gives rise is quite definite. Further, the gland is closely related to the upper border of the aortic arch and to the large branches which arise from it. On this account, it may be difficult to distinguish the tumour from an aneurism, when it is palpated in the jugular (supra-sternal) notch. Owing to the narrowness of the area in which the examination is carried out, it may be impossible to determine whether the pulsation is expansile or whether it is merely transmitted from the vessels.

Very little is known with regard to the functions of the thymus, and its relation to such conditions as *myasthenia gravis*, in which it is very frequently the seat of pathological changes, is not as yet properly understood.

The **Glomus Caroticum** (**Carotid Body**) is a small structure which is situated on the dorsal aspect of the bifurcation of the common carotid artery. It is richly supplied with blood and lymph vessels and it receives numerous branches from the sympathetic system. It contains numerous chromophil cells, but the nature of the internal secretion is still unknown, and the relation of the gland to disease has not been fully studied.

The **Glomus Coccygeum** (**Coccygeal Body**) is a small structure which lies on the pelvic surface of the coccyx behind the rectum. Although it is usually described as one of the ductless glands, it seems very doubtful whether it is not merely an adjunct of the circulatory system, with no special internal secretion.

GLOSSARY

Old Name.	B.N.A. (or English Translation).
Annulus ovalis	Limbus fossæ ovalis
Antecubital fossa	Cubital fossa
Appendix, vermiform	Vermiform process
Aqueduct of Sylvius	Cerebral aqueduct
Arteries—	**Arteries—**
Capsular	Supra-renal
Circle of Willis	Arterial circle
Cœliac axis	Cœliac
Coronary (of stomach)	Left gastric
Cremasteric	External spermatic
Deep epigastric	Inferior epigastric
Facial	External maxillary
Gluteal	Superior gluteal
Inferior coronary dental	Inferior labial alveolar
Internal iliac	Hypogastric
Meningeal, small	Meningeal, accessory
Pyloric	Right gastric
Sciatic	Inferior gluteal
Spermatic	Internal spermatic
Superior coronary dental	Superior labial alveolar
Thoracic axis	Thoraco-acromial
Thyroid axis	Thyreo-cervical trunk
Arytæno-epiglottidean folds	Ary-epiglottic folds
Auricle (of heart)	Atrium
Auricular appendix	Auricle
Auriculo-ventricular bundle	Atrio-ventricular bundle
groove	Coronary sulcus
orifice	Atrio-ventricular orifice
Bartholin's glands	Vestibular glands
Bicipital fascia	Lacertus fibrosus
Bulb of penis	Urethral bulb
Capsule of tenon	Fascia bulbi
Cartilages, semilunar	Menisci
Circumvallate papillæ	Vallate papillæ

Old Name.	B.N.A. (or English Translation).
Cornua (of spinal cord)	Columns
Corpus spongiosum penis	Corpus cavernosum urethræ
Cowper's glands	Bulbo-urethral glands
Crico-thyroid membrane (central part)	Crico-thyreoid ligament
(lateral part)	Conus elasticus
Crural canal	Femoral canal
ring	ring
Douglas, pouch of	Utero-rectal pouch
semilunar fold of	Linea semicircularis
Ductus venosus, obliterated	Ligamentum venosum
Eminentia teres	Facial colliculus
Epicranial aponeurosis	Galea aponeurotica
Epididymis, globus major of	Head of epididymis
minor of	Tail of epididymis
Fascia, infundibuliform	Fascia, internal spermatic
intercolumnar	external spermatic
Fenestra, ovalis	Fenestra vestibuli
rotunda	cochleæ
Fissure, calloso-marginal	Sulcus cinguli
dentate	Hippocampal fissure
parallel	Temporal sulci (superior and middle)
of Rolando	Central sulcus
of Sylvius	Lateral fissure
Flexure, hepatic (of colon)	Right colic flexure
splenic (of colon)	Left colic flexure
Fossa of Rosenmüller	Pharyngeal recess
Galen, veins of	Internal cerebral veins
great vein of	Great cerebral vein
Gangliated cord of sympathetic	Sympathetic trunk
Ganglion, Gasserian	Ganglion, semilunar
jugular	superius
lenticular	ciliary
of Meckel	spheno-palatine
of root	jugular
semilunar	cœliac
of trunk	nodosum
Wrisberg	cardiac
Gyrus, ascending frontal	Gyrus, anterior central
parietal	posterior central
callosal	cinguli
Highmore, antrum of	Maxillary sinus
Hunter's canal	Adductor canal
Hydatids of Morgagni	Appendices testis
Ilio-tibial band	Ilio-tibial tract
Incisura temporalis	Rhinal fissure
Inferior (*in describing relationships in limbs*)	Distal

Old Name.	B.N.A. (or English Translation).
Inter-articular fibro-cartilage	Articular disc
Intervertebral disc	Intervertebral fibro-cartilage
Island of Reil	Island
Lamina cinerea	Lamina terminalis
Larynx, sinus of	Ventricular appendix
upper aperture of	Laryngeal aditus
Lesser sac	Omental bursa
Ligaments—	**Ligaments—**
Anterior annular, of ankle	Transverse and Cruciate
of wrist	Transverse carpal
common	Anterior longitudinal
Cotyloid	Labrum glenoidale
External annular, of ankle	Peroneal retinacula
arcuate	Lateral lumbo-costal arch
lateral, of ankle	Lateral
of elbow	Radial collateral
of knee	Fibular collateral
Gimbernat's	Lacunar
Glenoid	Labrum glenoidale
Inferior calcaneo-scaphoid	Plantar calcaneo-navicular
thyro-arytænoid	Vocal
Internal annular, of ankle	Laciniate
arcuate	Medial lumbo-costal arch
lateral, of ankle	Deltoid
of elbow	Ulnar collateral
of knee	Tibial collateral
Mucosum	Patellar synovial fold
Orbicular	Annular
Ovario-pelvic	Suspensory, of ovary
Posterior annular, of wrist	Dorsal carpal
common	Posterior longitudinal
Poupart's	Inguinal
Rhomboid	Costo-clavicular
Sacro-sciatic, great	Sacro-tuberous
small	Sacro-spinous
Subflavum	Flavum
Triangular, superficial layer	Inferior fascia of uro-genital diaphragm
deep layer	Superior fascia of uro-genital diaphragm
Lobe, caudate (of liver)	Caudate process
Spigelian	lobe
Marshall, vestigial fold of	Ligamentum venæ cavæ sinistræ
Mastoid antrum	Tympanic antrum
Meatus, external auditory	Meatus, external acoustic
urinarius	External orifice of urethra
Middle ear	Tympanum
Monro, foramina of	Interventricular foramina

Old Name.	B.N.A. (or English Translation).
Morgagni, columns of	Rectal columns
Muscles—	**Muscles—**
Abductor minimi digiti pollicis	Abductor digiti quinti pollicis brevis
Accessorius (of foot)	Quadratus plantæ
Adductor obliquus pollicis	Adductor pollicis, pars obliqua
transversus pollicis	pars transversa
Ary-vocalis	Vocalis
Brachialis anticus	Brachialis
Compressor urethræ	Deep transverse perineal
Conjoined tendon	Falx inguinalis
Crureus	Vastus intermedius
Ejaculator urinæ	Bulbo-cavernosus
Erector clitoridis	Ischio-cavernosus
penis	Ischio-cavernosus
spinæ	Sacro-spinalis
Extensor ossis metacarpi pollicis	Abductor pollicis longus
primi internodii pollicis	Extensor pollicis brevis
secundi internodii pollicis	longus
Levator anguli scapulæ	Levator scapulæ
Orbicularis palpebrarum	Orbicularis oculi
Palato-glossus	Glosso-palatinus
pharyngeus	Pharyngo-palatinus
Pronator radii teres	Pronator teres
Psoas magnus	Psoas major
Scalenus anticus	Scalenus anterior
posticus	posterior
Serratus magnus	Serratus anterior
Supinator brevis	Supinator
longus	Brachio-radialis
Tendo Achillis	Tendo calcaneus
Tensor fasciæ femoris	Tensor fasciæ latæ
Tibialis anticus	Tibialis anterior
posticus	posterior
Transversalis	Transversus
Vastus externus	Vastus lateralis
internus	medialis
Nasal duct	Naso-lacrimal duct
Nerves—	**Nerves—**
Arnold's	Auricular branch of vagus
Auditory	Acoustic
of Bell	Long thoracic
Circumflex	Axillary
Communicans fibularis	Anastomotic peroneal
tibialis	Medial sural
Cranial	Cerebral
Crural, anterior	Femoral

Old Name.	B.N.A. (or English Translation).
Nerves, *continued*—	**Nerves**, *continued*—
Dental	Alveolar
Dorsal	Thoracic
External cutaneous, of musculo-spiral	Dorsal antibrachial cutaneous
of thigh	Lateral cutaneous
respiratory	Long thoracic
saphenous	Suralis
Genito-crural	Genito-femoral
crural branch of	Lumbo-inguinal
genital branch of	External spermatic
Intercosto-humeral	Intercosto-brachial
Internal cutaneous, of musculo-spiral	Dorsal brachial cutaneous
of thigh	Medial cutaneous
of upper limb	Medial antibrachial cutaneous
lesser	brachial cutaneous
Interosseous, anterior	Interosseous, volar
posterior	dorsal
of Jacobson	Tympanic
Long buccal	Buccinator
pudendal	Perineal branch of posterior cutaneous of thigh
saphenous	Saphenous
Malar	Zygomatico-facial
Maxillary, inferior	Mandibular
superior	Maxillary
Middle cutaneous, of thigh	Intermediate cutaneous
Musculo-cutaneous, of leg	Superficial peroneal
Musculo-spiral	Radial
Orbital	Zygomatic
Palmar cutaneous	Volar cutaneous
Pneumogastric	Vagus
Popliteal, external	Common peroneal
internal	Tibial
Primary divisions	Rami
Pudic, internal	Pudendal
Radial	Superficial division of radial
Recurrent laryngeal	Recurrent
to Rhomboids	Dorsalis scapulæ
Sciatic, great	Sciatic
small	Posterior cutaneous, of thigh
Small occipital	Lesser occipital
Spinal accessory	Accessory
Subscapular, long	Thoraco-dorsal
Supra-acromial	Supra-clavicular, posterior
clavicular	intermediate
sternal	anterior
Tibial, anterior	Deep peroneal

Old Name.	B.N.A. (or English Translation).
Nerves, *continued*—	**Nerves**, *continued*—
Tibial, posterior	Tibial
Vidian	of pterygoid canal
Nucleus, lenticular	Nucleus, lentiform
Omentum, gastro-hepatic	Omentum, lesser
gastro-splenic	Gastro-splenic ligament
Opening in adductor magnus	Hiatus tendineus
Optic disc	Porus opticus
Pacchionian bodies	Arachnoideal granulations
Parovarium	Ep-oöphoron
Perforated spot, anterior	Perforated substance, anterior
posterior	posterior
Petit, canal of	Spatia zonularia
Peyer's patches	Intestinal tonsils
Pituitary body	Hypophysis
Pleura, cervical	Cupula pleuræ
Pomum Adami	Laryngeal prominence
Pons Varolii	Pons
Popliteal space	Popliteal fossa
Receptaculum chyli	Cisterna chyli
Retinacula of ileo-cæcal valve	Frenula valvulæ coli
Ring, external abdominal	Ring, subcutaneous inguinal
internal abdominal	abdominal inguinal
Sacro-sciatic foramina	Sciatic foramina
Santorini, cartilages of	Corniculate cartilages
duct of	Accessory pancreatic duct
Saphenous opening	Fossa ovalis
Scarpa's triangle	Femoral triangle
Schlemm, canal of	Sinus venosus scleræ
Semicircular canals, membranous	Semicircular ducts
Septum, crurale	Septum femorale
lucidum	pellucidum
Sinus, lateral	Sinus, transverse
longitudinal, inferior	sagittal, inferior
superior	superior
piriformis	Recessus piriformis
pocularis	Prostatic utricle
of Valsalva	Aortic sinus
Sphenoidal fissure	Superior orbital fissure
Spheno-maxillary fissure	Inferior orbital fissure
Spinal cord	Spinal medulla
Socia parotidis	Accessory parotid
Stenson's duct	Parotid duct
Superior (*in describing relationships in limbs*)	Proximal
Tænia semicircularis	Stria terminalis
Temporo-maxillary joint	Temporo-mandibular joint
Tonsil, faucial	Tonsil, palatine
Tube, Eustachian	Tube, auditory

Old Name.	B.N.A. (or English Translation).
Tube, Fallopian	Tube, uterine
Turbinated bones	Conchæ
Urethra, spongy	Urethra, cavernous part of
Valve, ileo-cæcal	Valve, colic
Vas deferens	Ductus deferens
Veins of Marshall	Oblique vein of left atrium
saphenous, internal	Great saphenous vein
Veins, prostatic plexus of	Pudendal plexus
Velum interpositum	Tela chorioidea
Vena azygos major	Vena azygos
minor inferior	hemiazygos
superior	accessoria
Ventricle, fifth	Cavum septi pellucidi
lateral, descending horn of	Ventricle, lateral, inferior horn of
Verumontanum	Urethral crest
Vieussens, valve of	Superior medullary velum
Vocal cords, false	Ventricular folds
true	Vocal folds
Wharton's duct	Submaxillary duct
Winslow, foramen of	Epiploic foramen
Wirsung, duct of	Pancreatic duct
Wrisberg, cartilages of	Cuneiform cartilages

INDEX

Abdominal tumours, 241, 260, 323.
Acoustic centres, higher, 9.
  lower, 89.
  meatus, external, 198.
    foreign bodies in, 199.
    referred pain in, 199.
    syringing of, 200.
  nerve, 87.
  radiation, 35.
Acromegaly, 54, 401.
Acute anterior poliomyelitis, 46.
Addison's disease, 408.
Adenoids, 201, 330.
Allantois, 286, 369.
Alternate hemi-anæsthesia, 45, 87.
Ampulla of Vater, 263, 269.
Anal canal, 283.
  fissure, 183, 283, 285.
  valves, 283.
Angina pectoris, 308.
    referred pain of, 192, 309.
Angio-neurotic œdema, 228.
Anosmia, 16, 50.
Anterior fontanelle, 42.
    closure of, 43.
  perforated substance, 16.
Aorta, abdominal, 322.
    aneurism of, 322, 323.
  arch of, 318.
    aneurism of, 319.
  ascending, 318.
    aneurism of, 318.
  sinuses of, 318.
  thoracic, descending, 322.
Apical phthisis, 351, 352.
Appendicitis, pain in, 278, 279.
  viscero-motor reflex in, 279.
Appendix. *See* Vermiform process.
Aqueous humor, 216.
Arachnoid, 110.
Arch, glosso-palatine, 226.
  pharyngo-palatine, 226.
Arches of foot, 176.
Area, aortic, 299.
  bicuspid (mitral), 300.
  pulmonary, 299.
  tricuspid, 300.
Argyll-Robertson pupil, 54, 67.
Arterial circle (of Willis), 121.
Arterio-sclerosis, 218.
Artery or Arteries—
  anterior ciliary, 211.
    spinal, 46.
  basilar, 120.
  carotid, internal, 118, 203.
  centralis retinæ, 217.
  cerebral, anterior, 120.
    middle, 119.
      embolus in, 121.
    posterior, 120.
  of cerebral hæmorrhage, 33, 119.
  hepatic, 261.
  hypogastric, 305.
  iliac, common, 322.
  innominate, 321.
    aneurism of, 322.
  lenticulo-optic, 119.
  lenticulo-striate, 119.
  middle meningeal, 116.
  ovarian, 395.
  pulmonary, 323.
  splenic, 246.
  uterine, 392.
  vertebral, 120.
Ary-epiglottic fold, 332.
Arytænoid cartilage, 330.
Ascites, 241, 274.
Astereognosis, 10, 30.
Asthma, spasmodic, 356.
Atresia ani, 285, 287.

Foramen ovale, 293, 303.
persistent, 306.
of Winslow. *See* Epiploic foramen.
Fornix, 14, 24.
Fossa, ischio-rectal, 283.
ovalis, 293.
ovarica, 393.
Frontal sinus, 327.

Gall-bladder, 261.
development of, 264.
fundus of, 261.
nerve-supply of, 264.
referred pain of, 265.
Gall-stones, impaction of, 263.
Ganglion impar, 188.
Garland's curve, 346.
Gastric referred pain, 250.
secretion, 248.
ulcer, 250.
perforation of, 242.
Gastro-colic ligament, 237.
Gastro-splenic ligament, 238.
Geniculate body, lateral, 30, 51.
medial, 19, 89.
ganglion, 80.
Genital tubercle, 370.
Gerota's space, 360.
Glabella, 7.
Glaucoma, 214, 216.
Gleet, 379.
Glomus caroticum, 413.
coccygeum, 414.
Grey rami communicantes, 185.
Gums, lymph vessels of, 225.
mucous membrane of, 225.
Gyrus, angular, 9.
anterior central, 5.
blood-supply of, 119.
lesions of, 6.
surface marking of, 8.
cinguli (callosal gyrus), 12.
fornicatus (limbic lobe), 12.
hippocampal, 12.
lingual, 18.
middle frontal, 8.
posterior central, 5.
superior parietal, 9.
temporal, 9.
supramarginal, 9.

Hæmatemesis, 274, 275.
Hæmorrhoids, internal, 274, 275, 284.
Heart, 292.
accelerator nerves of, 187.
action of, 300.
apex-beat of, 294, 297, 298.
atria (auricles) of, 292, 293.
atrio-ventricular orifices of, 293.
block, 313.
blood-supply of, 310.
congenital anomalies of, 306.
development of, 302.
dilatation and hypertrophy of, 297, 298.
displacement of, 297, 298.
inhibitory nerves of, 98, 308.
musculature of, 310.
nerve-supply of, 307.
percussion of, 296.
rhythm, 312.
sounds, 300.
surface marking of, 294.
in child, 298.
valves of, 293, 294.
surface marking of, 299.
ventricles of, 293, 294.
Hemi-anæsthesia, 35.
Hemianopia, heteronymous, 54.
homonymous, 13, 35, 54.
quadrantic, 13.
Hemiplegia, 35.
Herpes zoster, 162.
Hyaloid membrane, 216.
Hydrocephalus, 24, 27, 111.
Hydrothorax, 317.
Hyperacousis, 80, 205.
Hypogastric plexus, 188.
Hypoglossal nerve, 104.
Hypophysis, 400.
relations of, 401.
stalk of, 16.
tumours of, 54, 401.
Hypospadias, 371.
Hysterectomy, 393.

Icterus neonatorum, 306.
Ileo-cæcal valve. *See* Colic valve.
Ileum, 255.
Ilio-tibial tract, 172.
Insula (of Reil), 10, 30.
Intentional tremor, 22.

Internal capsule, 32, 33, 35.
acoustic fibres of, 89.
lesions of, 35.
motor fibres of, 33.
sensory fibres of, 35.
Interpeduncular fossa, 16.
Interventricular foramen, 2, 15, 26.
Intestine, development of, 278.
developmental anomalies of, 285.
large, 276.
irrigation of, 284.
nerve-supply of, 284.
referred pain of, 285.
small, 253.
nerve-supply of, 257.
referred pain of, 257.
secretion of, 257.
Intracranial tension, 42, 113.
Intraocular tension, 214.
Intraorbital hæmorrhage, 210.
Intrapontine hæmorrhage, 86.
Iridectomy, 216.
Iridodonesis, 216.
Iris, 214.
nucleus, 52.
Iritis, 214.
Isthmus faucium, 226.

Jaundice, 264.
Jejunum, 253.
Joint sense, 43, 45.
Jugular bulb, 301.

Kidney, 357.
capsule of, 360.
floating, 360.
movable, 360.
nerve-supply of, 361.
palpation of, 360.
relations of, 357.
surface marking of, 357.
tumours of, 361.

Labia majora, 387.
minora, 387.
Labyrinth, membranous, 206.
osseous, 206.
Lacrimal apparatus, 208.
ducts, 208.
gland, 65, 208.
nerve-supply of, 209.
sac, 208.
secretion, 209.
Lamina rostralis, 28.
Laryngeal intubation, 332.
paralysis, 338.
prominence, 330.
Laryngoscopic examination, 332.
Larynx, 330.
aditus of, 331.
muscles of, 335.
ventricle of, 334.
vestibule of, 332.
Lateral fillet, 89.
fissure (of Sylvius), 8.
rami of, 9.
pyramidal tract, 37.
ventricle of brain, 2, 23.
Lead poisoning, 140.
Lens, crystalline, 215.
Lentiform nucleus, 32.
Lesser sac. *See* Omental bursa.
Lieno-renal ligament, 239.
Ligamentum arteriosum, 306.
Light reflex, 52.
Limbs, development of, 157.
Linea semilunaris, 262.
Liver, 257.
cirrhosis of, 274.
development of, 264.
downward displacement of, 258.
in infants, 259.
inferior border of, 259.
lobes of, 260.
nerves of, 264.
new growth in, 260.
percussion of, 259.
referred pain of, 265.
Reidel's lobe of, 259.
surface marking of, 259.
surfaces of, 258, 260.
transverse fissure of. *See* Porta hepatis.
tropical abscess of, 258, 265.
rupture of, 258, 261, 353.
venous congestion of, 261.
venous pulsation in, 261.
Lombardi's "varicose zone of alarm," 351.
Lumbar plexus, 163.
puncture, 41.
Lumbo-sacral cord, 170.
Lung, 348.
apex of, 349, 350, 351.
base of, 352.

Lung, *continued*—
fissures of, 348, 349, 350.
lobes of, 348, 349.
lymph vessels of, 353.
nerve-supply of, 356.
surface marking of, 349.
Lymph glands, anterior auricular, 222.
deep cervical, 222, 249.
external iliac, 388.
hypogastric, 388.
mesenteric, 240, 256.
subinguinal, 388.
submaxillary, 221.
submental, 225.
Lymphatic duct, right, 324.

Macula lutea, 218.
Main en griffe, 149.
Mandibular nerve, 69.
Mastoid antrum. *See* Tympanic antrum.
Maxillary nerve, 67.
sinus, 327.
M'Burney's point, 279.
Meckel's diverticulum, 285, 286.
Mediastinal tumours, 315, 413.
Mediastinitis, 291.
Medulla oblongata, 21.
Meibomian glands. *See* Tarsal glands.
Menière's disease, 90, 208.
Meningitis, basal, 54, 111.
cerebro-spinal, 111.
Mesencephalon, 18.
Mesentery, 240.
Mesocolon, transverse, 237.
Mesosalpinx, 386.
Mesovarium, 386, 394.
Microcephalus, 43.
Micturition, act of, 373.
frequency of, 277, 279, 373.
reflex, 373.
Mid-brain, 18.
hæmorrhage in, 39.
Middle ear, 200.
inflation of, 202, 329.
Millard-Gubler syndrome, 86.
Monoplegia, cortical, 7.
Motor centres, higher, 5.
fibres, path of, 37.
Mouth, 225.
Müllerian duct, 381, 397.
Muscle or Muscles—
of abdominal wall, 161.
adductor pollicis, 147.
adductor, of thigh, 169.
biceps brachii, 134.
femoris, 174.
brachialis (anticus), 134.
brachio-radialis, 140.
buccinator, 82.
ciliary bundle, 210.
coraco-brachialis, 134.
cremaster, 165, 364.
crico-arytænoideus lateralis, 337.
posterior, 336.
crico-thyreoid, 97, 335.
paralysis of, 339.
crureus. *See* Vastus intermedius.
deltoid, 137.
diaphragm, 354.
paralysis of, 355.
digastric, 72, 81.
dilatator pupillæ, 214.
dorsal, of forearm, 141.
extensor carpi radialis longus, 140.
digitorum brevis, 180.
longus, 180.
hallucis longus, 180.
external oblique, 162.
flexor carpi radialis, 150.
ulnaris, 144.
digitorum longus, 176.
profundus, 151.
sublimis, 150.
hallucis longus, 176.
pollicis longus, 150.
gastrocnemius, 175.
genio-glossus, 107.
genio-hyoid, 106.
glutæus maximus, 172.
medius, 172.
minimus, 172.
gracilis, 169.
of hypothenar eminence, 145.
inferior oblique (of orbit), 57.
rectus, 57.
infraspinatus, 131.
internal oblique, 162.
interossei, dorsal, of hand, 147.
volar (palmar), 146.
intrinsic, of eye, 58.
of larynx, 335.

Muscle or Muscles, *continued*—
lateral rectus, 58.
paralysis of, 60.
latissimus dorsi, 136.
levator ani, 184.
palpebræ superioris, 57.
lumbricals, of hand, 145.
masseter, 70.
of mastication, 70.
medial rectus, 58.
mylo-hyoid, 72.
obturator externus, 169.
internus, 173.
occipitalis, 81.
omo-hyoid, 106.
orbicularis oculi (palpebrarum), 57, 82.
paralysis of, 57, 82.
oris, 84.
of the orbit, 57.
motor centre for, 8.
paralysis of, 58.
palmaris longus, 150.
papillary, of heart, 293.
pectineus, 166.
pectoralis major, 133.
congenital deficiency of, 134.
minor, 142.
of perineum, 184.
peronæus brevis, 180.
longus, 179.
tertius, 180.
plantaris, 175.
popliteus, 176.
pronator quadratus, 150.
teres, 150.
psoas major, 163.
reflex contraction of, 279.
pterygoid, 72.
quadratus femoris, 173.
quadriceps femoris, 166.
rectus abdominis, 161.
femoris, 166.
rhomboid, 132.
sartorius, 166.
semimembranosus, 174.
semitendinosus, 174.
serratus anterior, 132.
soleus, 175.
sphincter pupillæ, 214.
paralysis of, 61.
stapedius, 205.
Muscle or Muscles, *continued*—
sterno-hyoid, 106.
sterno-mastoid, 103.
sterno-thyreoid, 106.
stylo-hyoid, 82.
stylo-pharyngeus, 94.
subclavius, 131.
subscapularis, 136.
superior oblique (of orbit), 58.
paralysis of, 60.
superior rectus, 57.
supraspinatus, 131.
temporal, 70.
tensor fasciæ latæ, 172.
tympani, 205.
teres major, 136.
minor, 137.
of thenar eminence, 151.
atrophy of, 47.
thyreo-hyoid, 106.
tibialis anterior, 180.
posterior, 176.
of tongue, 107.
transversus, 162.
trapezius, 103.
triceps, 140.
vastus intermedius, 166.
lateralis, 166.
medialis, 166.
vocalis, 336.
Muscle sense, 43.
Musculo-spiral paralysis. *See* Radial paralysis.
Myasthenia gravis, 413.
Myelitis, transverse, 48.
Myxœdema, 411.

Nasal cavity, 325.
lateral wall of, 325.
openings into, 325, 327.
Nasal duct. *See* Naso-lacrimal duct.
Nasal septum, 325.
deviation of, 325.
Naso-lacrimal duct, 208, 324.
Naso-pharynx, 329.
Nerve or Nerves
abducent, 56.
lesions of, 58, 60.
accessory, 101.
lesions of, 103.
neuritis of, 104.

Nerve or Nerves, *continued*—
acoustic, 87.
lesions of, 89.
alveolar (dental) inferior, 75.
superior, 69.
ansa hypoglossi, 106.
anterior crural. *See* Nerve—femoral.
auriculo-temporal, 74.
axillary (circumflex), 137.
buccinator (long buccal), 75.
cerebral, 48.
chorda tympani, 84.
cochlear, 87.
lesions of, 89.
common peroneal (external popliteal), 178.
of deep sensibility, 122.
dorsal cutaneous, of forearm, 138.
of penis, 184.
dorsalis scapulæ, 131.
of epicritic sensibility, 122.
external spermatic, 165.
facial, 79.
intracranial lesions of, 86.
nucleus of, 79.
lesions of, 86.
peripheral lesions of, 82.
femoral, 166.
articular branches of, 166.
cutaneous branches of, 167.
motor branches of, 166.
paralysis of, 167.
fifth cerebral, 61.
frontal, 65.
genito-femoral, 165.
glosso-pharyngeal, 91.
lesions of, 92.
lingual branches of, 92.
tympanic branch of, 92.
gluteal, inferior, 172.
superior, 172.
hæmorrhoidal, inferior, 183.
hypoglossal, 104.
lesions of, 107.
ramus descendens of, 106.
ilio-hypogastric, 163.
ilio-inguinal, 163.
infra-orbital, 69.
infra-trochlear, 65.
intercostal, 160.
intercosto-brachial, 160.
Nerve or Nerves, *continued*—
intermediate cutaneous (of thigh), 167.
intermedius (of Wrisberg), 80.
lacrimal, 65.
laryngeal, external, 97.
internal, 97.
superior, 97.
lateral cutaneous, of forearm, 134.
of thigh, 165.
lingual, 75.
long ciliary, 65.
thoracic (of Bell), 132.
lumbo-sacral cord, 170.
mandibular (inferior maxillary), 69.
injection of alcohol into, 69.
maxillary (superior), 67.
injection of alcohol into, 68.
medial cutaneous, of arm, 143.
of forearm, 144.
of thigh, 167.
sural, 176.
median, 149.
digital branches of, 151.
lesions of, 152.
mental, 75.
musculo-cutaneous, 134.
musculo-spiral. *See* Nerve—radial.
naso-ciliary (nasal), 65.
obturator, 168.
lesions of, 170.
occipital, greater, 124.
third, 124.
oculo-motor, 20, 54.
lesions of, 58, 60.
olfactory, 48.
ophthalmic, 64.
optic, 50.
course of fibres of, 50.
lesions of, 52.
perineal, 184.
peroneal, common (external popliteal), 178.
deep (anterior tibial), 180.
superficial (musculo-cutaneous), 178.
petrosal, lesser superficial, 92.
phrenic, 4, 126, 264.
plantar, lateral, 178.
medial, 177.

Nerve or Nerves, *continued*—
popliteal, external. *See* Nerve—common peroneal.
internal. *See* Nerve—tibial.
posterior cutaneous, of thigh, 182.
of protopathic sensibility, 122.
of the pterygoid canal (Vidian), 68.
pudendal, 183.
radial (musculo-spiral), 138.
deep branch of, 140.
paralysis of, 141.
superficial branch of, 141.
ramus descendens cervicalis, 106.
recurrent (laryngeal), 99, 338.
compression of, 99, 338.
roots, 123.
saphenous, 167.
sciatic, 173.
neuritis of, 181.
paralysis of, 182.
sensory, classification of, 121.
spinal, rami of, 123.
splanchnic, 187.
subscapular, upper, 136.
lower, 136.
supraorbital, 65.
suprascapular, 131.
supratrochlear, 65.
sural, 176.
sympathetic, 185.
thoraco-dorsal, 136.
tibial, 175.
trigeminal, 61.
motor paralysis of, 73.
sensory root of, 62.
lesions of, 77.
trochlear, 20, 55.
lesions of, 58, 60.
ulnar, 144.
deep branch of, 145.
vagus, 94.
auricular branch of, 96.
cardiac branches of, 98.
lesions of, 98.
distribution of, 100.
lesions of, 100.
neuritis of, 101.
pharyngeal branch of, 96.
vestibular, 90.
volar interosseous, 150.
zygomatic, 68.

Nervous system, 1.
development of, 1.
parts of, 5.
Neurone, 3.
Nose, 325.
meatuses of, 325.
Nucleus of abducent nerve, 56.
ambiguus, 91, 94, 101.
dorsalis, 94.
of oculo-motor nerve, 39, 54.
lesions of, 60.
of trochlear nerve, 55.

Œdema glottidis, 335.
Œsophageal bougie, 231.
plexus, 100.
Œsophagus, 230.
blood-supply of, 232.
nerves of, 232.
obstruction of, 231.
radiographic examination of, 232.
Olfactory bulb, 15.
centres, higher, 16.
nerves, 48.
congenital absence of, 15.
tract, 15.
Olivary nucleus, 21.
Olive, 21.
Omental bursa (lesser sac), 237.
boundaries of, 237.
Omentum, greater, 236.
lesser, 236.
Ophthalmic nerve, 64.
Ophthalmoscopic examination, 216.
Optic chiasma, 16, 50.
lesions of, 54.
pressure on, 401.
disc. *See* Porus opticus.
nerve, 16, 50.
radiation, 35.
tract, 16.
lesions of, 52.
Otic ganglion, 70.
Otitis media, 200, 202.
Otoscopic examination, 202.
Ovarian cyst, 394, 406.
pain, 395.
Ovary, 393.
development of, 398.
ligaments of, 387, 394.
lymph vessels of, 395.
Ovulation, 396.

Palatal paralysis, 96.
Pancreas, 266.
  accessory duct of, 269.
  annular, 270.
  cysts of, 268.
  development of, 269.
  duct of, 269.
    obstruction of, 269.
  malignant disease of, 268.
  tumours of, 268.
Pancreatic infantilism, 271.
  secretion, 270.
Paracentesis abdominis, 241.
  pericardii, 291.
  thoracis, 347.
  of tympanic membrane, 203.
Paracentral lobule, 12.
Paralysis, lower neurone, 3.
  upper neurone, 3.
Paraplegia, 323.
Parathyreoid gland, 412.
Parietal tuber (eminence), 9.
Parieto-occipital fissure, 12.
Parotid duct, 222.
  gland, 222.
    accessory, 224.
    lymph vessels of, 224.
Parotitis, 223.
Parovarium. *See* Ep-oöphoron.
Pelvis, 381.
  bony, 381.
  conjugates of, 383.
  floor of, 384.
  Nægele, 382.
  Roberts, 382.
  spondylolisthetic, 382.
Penis, development of, 371.
Pepsin, 248.
Perforated substance, anterior, 16, 32.
    posterior, 16.
Pericardial effusion, 288, 289, 291.
Pericarditis, 230, 289.
Pericardium, 288.
  adherent, 291.
Perilymph, 207.
Perineum, muscles of, 184.
  rupture of, 388.
Peritoneum, 234.
  compartments of, 240.
  functions of, 240
  nerve-supply of, 241.
Peyer's patches. *See* Tonsil, intestinal.
Pharyngeal plexus, 96.
  recess, 329.
Pharynx, nasal part of, 329.
  oral part of, 226.
Phrenic nerve, 126.
Phrenico-colic ligament, 404.
Pia mater, 110.
Pillars of fauces. *See* Arches, glosso-palatine and pharyngo-palatine.
Pituitary body. *See* Hypophysis.
Planes of abdomen, 233.
Pleura, 341.
  nerve-supply of, 347.
Pleural reflection, lines of, 344.
  sac, lower limit of, 345.
    surface marking of, 343.
    exploration of, 346.
Pleurisy, diaphragmatic, 348.
Pleuritic effusion, 345.
Plica sublingualis, 224.
Plicæ circulares, 256.
Pomum Adami. *See* Laryngeal prominence.
Pons (Varolii), 20.
Porta hepatis, 261.
Portal circulation, 271.
  obstruction, 274.
    caput Medusæ of, 276.
Porus opticus, 216.
Pre-auricular point, 8.
Prepuce, 379.
  adherent, 380.
Presbyopia, 215.
Proctodæum, 287.
Progressive muscular atrophy, 46, 108, 152.
Promontory, sacral, 382.
Prostate, 374.
  hypertrophy of, 374.
Prostatic utricle, 379.
Protopathic sensibility, 122.
Pseudo-bulbar paralysis, 36.
Pseudo-ptosis, 189, 210.
Ptosis, 57, 60.
Ptyalin, 225.
Pudendal plexus, 183.
Pulmonary plexus, 100.
Pulsation, epigastric, 297.
Pulse tracing, 301.

Pulse tracing, venous, 311.
Pulvinar, 29, 51.
Pupillary fibres, 52.
Pylorus, 242.
  adhesions at, 248.
Pyramidal tract, 37.
  mode of termination of, 37.
Pyramids, 21, 37.
  decussation of, 21, 37.

Radial paralysis, 141.
Recessus piriformis, 332.
Rectocele, 389.
Rectum, 281.
  digital examination of, 283.
  flexures of, 282.
  prolapse of, 283.
  valves of, 282.
Referred pain, 190.
Regions of abdomen, 233.
Reidel's lobe, 259.
Rennin, 248.
Residual urine, 374.
Respiration, movements of, 354.
  types of, 354.
Restiform body, 21, 22.
Retention of urine, 48.
Retina, 214.
Rima glottidis, 335.
  vestibuli, 333.
Round ligament of uterus, 391.

Saccule, 206.
Sacral plexus, 170, 283.
    pressure on, 171.
Sacral promontory, 382.
Salivary glands, 222.
  secretion, 225.
"Saturday night" paralysis, 138.
Sciatica, 171, 181, 283.
Sclera, 211.
Scleritis, 211.
Scotoma, 217.
Scrotum, development of, 371.
Secretin, 257, 270.
Segmental innervation of upper limb, 155, 157.
Semicircular canals, 206.
  ducts, 206.
Semilunar (Gasserian) ganglion, 62.
Semilunar ganglion. *See* Cœliac ganglion.
Seminal vesicle, 377.
Sensory centres, higher, 12.
  fibres, course of, 44.
    decussation of, 43, 44.
Septum, nasal, 325.
  pellucidum, 13.
Sinus, cavernous, 115.
    relations of, 116.
    septic thrombosis of, 116.
  pocularis. *See* Prostatic utricle
  sagittal, inferior, 114.
    superior, 112.
  straight, 114.
  transverse (lateral), 23, 114, 207.
  venosus scleræ (canal of Schlemm), 212.
Skull, fracture of, 49, 109.
Spastic paraplegia, 47.
Speech centre, motor, 9.
      blood-supply of, 119.
    visual, 9.
    written, 8.
      blood-supply of, 119.
Sphenoidal air sinus, 327.
Spheno-palatine (Meckel's) ganglion, 68.
Spinal medulla, 40.
    compression of, 48.
    lesions of, 45.
    structure of, 43.
Spino-thalamic tract, 44.
Splanchnics, pelvic, of Gaskell, 285.
Spleen, 403.
  contractions of, 406.
  enlargement of, 404.
  movable, 406.
  puncture of, 406.
  surface marking of, 404.
  venous congestion of, 274, 406.
Splenectomy, 406.
Stenosis, pulmonary, 307.
Stereognosis, centre for, 10.
Sternal angle, 294.
Stomach, 242.
  atony of, 248.
  bed, 245.
  capacity of, 249.
  cardiac orifice of, 242.
  development of, 249.
  fundus of, 242, 247.
  lymph vessels of, 249.
  nerve-supply of, 249.
  pyloric canal of, 243.

Stomach, *continued*—
radiographic examination of, 246.
relations of, 243.
secretion of, 248.
surface marking of, 243.
viscero-motor reflex of, 250.
viscero-sensory reflex of, 250.
Stomata, 240, 346.
Striæ acousticæ, 89.
Subcutaneous inguinal ring, 377.
Subdural fluid, 109.
Sublingual gland, 224.
Submaxillary ganglion, 76.
gland, 224.
duct of, 224.
Subphrenic abscess, intraperitoneal, 258.
Succus entericus, 257.
Supra-renal gland, 407.
Sympathetic ganglia, 186.
nervous system, 185.
cardiac branches of, 187.
lesions of, 188.
trunks, 185.
Syndrome of Weber, 39.
Syringo-myelia, 47.

Tabes mesenterica, 256.
Tarsal glands, 211.
Tarsi, 210.
Tartar, 225.
Taste, centres for, 18.
fibres, course of, 84.
Teeth, 219.
deciduous, 219.
eruption of, 219.
Hutchinson's, 220.
lymph vessels of, 221.
permanent, 219.
Tegmen tympani, 200.
Tegmentum, 18.
Tela chorioidea, 15, 23.
Tendons, division of, 122.
Tentorium cerebelli, 109.
Testis, 375.
development of, 380.
ducts of, 375.
nerve-supply of, 375.
Thalamus, 14, 29.
lesions of, 30.
Thoracic duct, 324.
compression of, 321.
Thoracic-ulnar analgesia, 160.
Thumb, abduction of, 147.
adduction of, 151.
Thymus gland, 290, 412.
tumours of, 413.
Thyreo-glossal cyst, 411.
duct, 411.
Thyreoid cartilage, 330.
gland, 409.
blood-supply of, 412.
development of, 411.
lymph vessels of, 412.
tumours of, 409.
Thyreoidism, 411.
Tic douloureux, 78.
Tongue, 226.
deviation of, 107.
lymph vessels of, 226.
muscles of, 107.
nerve-supply of, 75, 107.
paralysis of, 107.
Tonsil, intestinal, 256.
lingual, 226.
palatine, 228.
crypts of, 228.
hypertrophy of, 228.
lymph vessels of, 228.
pharyngeal, 329.
Tonsillitis, follicular, 228.
Torticollis, 104.
Torus tubarius, 329.
Trachea, 339.
Tracheal tugging, 288, 321.
Tractus solitarius, 85, 91.
Transverse myelitis, 48.
Traube's space, 244, 345.
Trigeminal nerve, 61.
compression of, 62.
nuclear lesions of, 61.
supranuclear lesions of, 61.
neuralgia, 77.
Tropical abscess of liver, 258, 317.
Tubal pregnancy, 396.
Tuber cinereum, 16.
Tunica vaginalis testis, 375.
Turbinated bones. *See* Conchæ.
Tympanic (mastoid) antrum, 114, 202, 205.
inflammation of, 206
relations of, 205.
membrane, 199, 202.
Typhoid fever, 279.

Uncus, 16.
Ureter, 361, 392.
calculi in, 363.
constrictions of, 362.
development of, 369.
nerve-supply of, 363.
Ureteral colic, 363.
muscular hyperalgesia in, 365.
testicular pain in, 364.
Urethra, 378.
cavernous part of, 379.
female, 399.
membranous part of, 379.
prostatic part of, 379.
stricture of, 379.
Urethral crest, 379.
Urethro-vaginal fistula, 387.
Urinary bladder, 365.
Uterine tube, 390, 395.
development of, 397.
fimbriæ of, 395.
ostium abdominale of, 396, 397.
Utero-sacral ligament, 391.
Uterus, 389.
bicornuate, 398.
blood-supply of, 392.
body of, 390.
broad ligament of, 385.
development of, 397.
displacement of, 391.
ligaments of, 391.
lymph vessels of, 393.
nerve-supply of, 393.
prolapse of, 389.
Utricle, 207.

Vagina, 387.
development of, 397.
lymph vessels of, 388.
malignant disease of, 388.
Vaginal examination, 387.
Vagus nerve, 94.
Valves, anal, 283.
colic (ileo-cæcal), 280.
rectal, 282.
venous, 301.
Valvulæ conniventes, 256.
Varicocele, 375.
Vas deferens. *See* Ductus deferens.
Vein or Veins; Vena or Venæ—
abdominal, superficial, 316.
azygos (major), 351.
Vein or Veins, *continued*—
of brain, 121.
cava inferior, 315.
obstruction of, 316.
superior, 314.
obstruction of, 314.
cerebral, great (of Galen), 27.
internal, 27.
hæmorrhoidal, 275, 284.
hepatic, 261, 317.
innominate, 314.
intercostal, 351.
jugular, external, 302.
internal, 301.
thrombosis of, 200.
meningeal, 117.
mesenteric, superior, 272.
ophthalmic, 115.
pampiniform plexus, 375.
para-umbilical, 275.
portal, 271.
obstruction of, 274.
viscera drained by, 272.
pterygoid plexus, 115.
pulmonary, 317.
splenic, 272, 406.
umbilical, 260, 275, 304.
Venous pulsation, 302, 311.
ventricular type of, 312.
Ventricle, fourth, 2, 15.
lateral, 23.
floor of, 23.
inferior horn of, 27.
tapping of, 27.
medial wall of, 26.
posterior horn of, 27.
tapping of, 27.
third, 15, 28.
floor of, 16, 28.
roof of, 29.
Ventricular folds, 333.
Vermiform process (appendix), 277.
development of, 278.
nerve-supply of, 278.
Vertebræ, erosion of, 321, 323.
Vesical calculus, 373, 380.
pain, 371.
Vesico-vaginal fistula, 387.
Viscera, nerve-supply of, 188.
Visceral pain, 192.
Viscero-motor reflex, 197.

Viscero-sensory reflex, 192.
Visual centres, higher, 10, 12.
blood-supply of, 120.
lower, 31.
fibres, lesions of, 32.
Vitello-intestinal duct, 286.
Vitreous body, 215.
Vocal cords, false. *See* Ventricular folds.
true. *See* Vocal folds.
Vocal folds, 334.
paralysis of, 320, 338.

Weber's syndrome, 39.
test, 90.
Wernicke's test, 52.
White rami communicantes, 185.
Winging of scapula, 133.
Wolffian body, 380.
duct, 369, 380.
Word-deafness, 89.
Word-hearing centre, 9.
blood-supply of, 119.
Word-seeing centre, 9.
blood-supply of, 119.
Wrist-drop paralysis, 140, 141.

Yolk-sac, 285.

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